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THESIS

TAILORING SYSTEMS ENGINEERING PROCESSES FOR RAPID SPACE ACQUISITIONS

by

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13. ABSTRACT (maximum 200 words)

The Self-Awareness Space Situational Awareness (SASSA) program is a congressionally initiated technology demonstration program run by the Air Force, Space and Missile System Center (SMC), Los Angeles Air Force Base. Initiated October 2008, SASSA is investigating the feasibility of a highly flexible and adaptable satellite payload system for detecting satellite threats, both natural and manmade. The SASSA program was given cost and schedule limitations with a mandate to deliver hardware for demonstration in 24 months, considered a "rapid acquisition" by AF and SMC standards. This study provides an assessment of how the SASSA program tailored systems engineering processes to implement a "rapid space acquisition." Acquisition and engineering standards define a roadmap for military procurements to produce the most effective product at the most reasonable cost. Refinement of these standards over time is critical to the continued success of acquisition systems to evolve a current and effective military. This study reviews the SASSA concept and technology demonstration, surveys standard systems engineering guidance, catalogues systems engineering processes tailored, and assesses effectiveness of this tailoring. This study will provide observation and assessment of real-world results, successful and unsuccessful, for the purposes of capturing and documenting lessons learned towards successfully accomplishing rapid space acquisitions.

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TAILORING SYSTEMS ENGINEERING PROCESSES FOR RAPID SPACE ACQUISITIONS

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ABSTRACT

The Self-Awareness Space Situational Awareness (SASSA) program is a congressionally initiated technology demonstration program run by the Air Force, Space and Missile System Center (SMC), Los Angeles Air Force Base. Initiated October 2008, SASSA is investigating the feasibility of a highly flexible and adaptable satellite payload system for detecting satellite threats, both natural and manmade. The SASSA program was given cost and schedule limitations with a mandate to deliver hardware for demonstration in 24 months, considered a "rapid acquisition" by AF and SMC standards. This study provides an assessment of how the SASSA program tailored systems engineering processes to implement a "rapid space acquisition." Acquisition and engineering standards define a roadmap for military procurements to produce the most effective product at the most reasonable cost. Refinement of these standards over time is critical to the continued success of acquisition systems to evolve a current and effective military. This study reviews the SASSA concept and technology demonstration, surveys standard systems engineering guidance, catalogues systems engineering processes tailored, and assesses effectiveness of this tailoring. This study will provide observation and assessment of real-world results, successful and unsuccessful, for the purposes of capturing and documenting lessons learned towards successfully accomplishing rapid space acquisitions.

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LIST OF ACRONYMS AND ABBREVIATIONS

AoA	Analysis of Alternatives
AMA	Analysis of Material Approaches
ACAT	Acquisition Category
AFRL	Air Force Research Laboratory
AFSCN	Air Force Satellite Control Network
AFSPC	Air Force Space Command
AF	Air Force
AI&T	Assembly, integration, and test
AM	Antenna Module
ASAT	Anti-Satellite
ATC	Assurance Technology Corporation (SASSA Contractor)
ATP	Authority to Proceed (as in contract award)
CCB	Change Control Board
CCS	Command, Control and Status Subsystem (SASSA program)
CDD	Capability Development Document
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CIU	Common Interface Unit
CM	Configuration Management
CONOP(S)	Concept of Operations
COTS	Commercial off the Shelf
cPCI	Compact Pre-Configured Interface
CTE	Critical Technology Elements
DAG	Defense Acquisition Guidebook
DAU	Defense Acquisition University
DoD	Department of Defense
DoDAF	Department of Defense Architecture Framework
DoDI	Department of Defense Instruction

DOORS	Distributed Object Oriented Requirements System
DOTMLPF	Doctrine, Organization, Training, Materiel, Logistics, Personnel and Facilities
DPA&E	Director, Program Analysis & Evaluation
DSC	Dedicated Stand alone Communication
EDU	Engineering Development Unit
EIA	Electronics Industries Association
ERB	Engineering Review Board
EVMS	Earned Value Management System
FFRDC	Federally Funded Research and Development Centers
FRB	Failure Review Boards
GAO	General Accounting Office
GPS	Global Positioning System (government program)
HDMI	High-Definition Multimedia Interface
HTTP	Hypertext Transfer Protocol
HW	Hardware
ICD	(1) Initial Capability Document
	(2) Interface Control Document
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute for Electrical and Electronics Engineers
IMP	Integrated Master Plan
IMS	Integrated Master Schedule
INCOSE	International Council on Systems Engineering
IPDT	Integrated Product Development Teams
IPT	Integrated Product Team(s)
ISR	Intelligence, Surveillance, and Recognizance
JCD	Joint Capabilities Document
JCID	Joint Capabilities Integration and Development
JCIDS	Joint Capabilities Integration and Development System
KDP	Key Decision Point

KPP	Key performance parameter
KSA	Key System Attribute
LAAFB	Los Angeles Air Force Base
LEO	Low Earth Orbit
MAJCOM	Major Command (as in Air Force Major Commands)
MATLAB	Mathematical Analysis Software (COTS)
MDA	Milestone Decision Authority
MDAP	Major Defense Acquisition Program
MIL-Spec	Military Specification
MIL-STD	Military Standard
MNS	Mission Needs Statement
MPA	Mission Planning and Analysis Subsystem (SASSA program)
NSA	National Security Agency
OIC	Officer in Charge
PCI	Pre-Configured Interface
PDR	Preliminary Design Review
PM	Program Management
PMP	Parts, Materials, and Processes Plan or Parts Management Plan
PO	Program Office
RAA	Responsibility, Authority, and Accountability
RF	Radio Frequency
RFP	Request for Proposal
RSPM	Receiver signal Processor Module (SASSA component)
RWR	Radar Warning Receiver
SA	Situation(al) awareness
SASSA	Self-Awareness Space Situational Awareness
SSA	Space Situational Awareness
SC	Space Craft
SDD	System Development and Demonstration
SDP	Software Development Plan

SDR	System Design Review
SE	Systems Engineering
SEDS	Systems Engineering Detailed Schedule
SEIT	System Engineering & Integration Team
SEMP	Systems Engineering Management Plan (Contractors)
SEMS	Systems Engineering Master Schedule
SEP	Systems Engineering Plan (Government)
SETA	System Engineering and Technical Assistance
SIS	Standard Interface Specification (as in SASSA program SIS)
SMC	Space and Missiles System Center
SOH	State of Health
SOO	Statement of (Government) Objectives
SOW	Statement of Work
SPO	System Program Office
SRD	System Requirements Document
SRD	System Requirements Document
SRR	System Requirements Review
SRS	Software Requirements Specification
SSA	Space Situational Awareness
SSR	Software Specification Review
SV	Space Vehicle
SW	Software
TPM	Technical Performance Measure
TRD	Technical Requirements Document
TRL	Technology Readiness Level
USAF	United States Air Force
USB	Universal Serial Bus
USSTRATCOM	United States Strategic Command
WIPT	Working level IPT (Integrated Product Team)
XML	Extensible Markup Language

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I. INTRODUCTION

A. BACKGROUND

Spurred by the 2007 Chinese Anti-Satellite (ASAT) event, the Self Awareness Space Situational Awareness (SASSA) technology demonstration program was established to evolve the concept of Space Situational Awareness (SSA), which would address local satellite awareness, as well as contribute to global awareness of space objects. SASSA has also sought to find a reasonable path for a more pervasive and accessible solution to local satellite threat warning, versus current satellite-specific implementations. The SASSA program utilizes the paradigm that an understanding of the local threat environment enables the possibility of action towards threat protection. A potential solution being demonstrated by SASSA is to develop adaptable and flexible space and ground elements whose primary aspects remain the same while peripherals are adapted to specific threat warning needs. This concept, once matured, may lead to a "one-size-fits-most" product line for threat warning systems. Conceptually the SASSA architecture would be capable of integrating various threat warning sensor suites with well-defined standard interfaces on satellite vehicles. This concept applied across the U.S.' space assets could dramatically increase our understanding of the natural and manmade space environment, ultimately enabling significantly enhanced protection capabilities for our national space assets.

B. PURPOSE

This thesis describes and evaluates the tailoring of SE guidance for DoD acquisitions for a smaller, rapid space acquisition program. An inherent assumption is that there is a standard body of systems engineering guidance provided to the DoD community from which to develop and draw direction for how to implement and apply systems engineering practices to such a program. This study captures and assesses tailored systems engineering guidance and documents lessons learned, applicable to like systems in the future, for effectively supporting the delivery of a rapid-paced space satellite payload acquisition.

C. RESEARCH QUESTIONS

The goal of this study is to use the SASSA program as a case study for the effectiveness of tailoring standard systems engineering processes such as: developing objectives, requirements, specifications, milestones reviews, assembly, integration and test (AI&T), and validation/ verification of requirements *in order to support the delivery of a rapid pace, cost constrained satellite payload acquisition.* The study questions investigated are as follows:

1) What are the standard systems engineering guidance sources available and expected to be used by DoD space program systems engineers?

- Means to find answer: Perform survey of DoD and industry standard systems engineering guidance sources available to DoD space program systems engineers.

2) What are the standard systems engineering processes that SASSA effectively tailored to be more effective for rapid acquisitions?

- Means to find answer: Observations/results from actual program, quantifiable data from program where possible.

3) Study Questions: What are the standard systems engineering processes that SASSA did not effectively modify to be more effective for rapid acquisitions?

- Means to find answer: Observations/results from actual program, quantifiable data from program where possible.

D. BENEFITS OF STUDY

This study provides a listing of DoD and industry standard systems engineering sources recommended to government personnel in performing systems engineering on DoD space programs. This list of sources comprises the body of source material, which defines "standard" SE processes. This provides a context for the observation and assessment of real world results in the implementation of tailored standard SE processes, both successful and unsuccessful. This is hoped to benefit process innovation of standard systems engineering guidance and standards in the DoD acquisition framework, which is critical to the continued success and optimization of acquisition systems to sustain a current and effective military. It may also benefit other military acquisitions which are of similar size and pace, especially rapid space acquisitions by observing actual tailored processes implemented and their lessons learned. Specifically, this thesis supports this through providing:

a) A listing of standard systems engineering guidance for DoD space programs
b) Real world examples of tailored SE processes for rapid space payload acquisitions
c) Evaluation of these processes for effectiveness towards rapid space acquisition
d) Observations and recommendations for improving SE processes for space acquisitions particularly rapid space acquisitions

E. SCOPE AND METHODOLOGY

1. Scope

The scope of this thesis topic is limited to identifying and analyzing systems engineering processes that have already been accomplished on an Air Force satellite payload acquisition from summer 2007 to present (currently post CDR). Firsthand experience provided from the researcher as well as other participants in the government program management and technical oversight team are used.

2. Methodology

The approach to accomplishing this study involved four phases. The first phase of this study started with a survey of industry and DoD standard systems engineering guidance documents to define a set of authoritative systems engineering source material. Once a body of authoritative material for SE guidance was established, then a survey of this material was conducted to find areas where the SASSA program tailored their SE practices.

The second phase compared and identified areas of difference between authoritative SE guidance identified and processes implemented in the SASSA program.

A catalogue of standard SE processes which were tailored for SASSA was created. The discussion includes a description of the standard guidance from the authoritative source documents, the corollary process implemented by SASSA, and an identification of the differences between the two.

The third phase utilized the data identified in phase two for tailored processes and attempted to assess whether or not each process implemented was successful or unsuccessful towards achieving the goal of a rapid space payload acquisition. For each process, a case was presented either advocating for or against the process implementation as effective or not effective.

The final phase of the study included capturing the conclusions drawn in the previous phases. The final chapter focused on the applications of the study. This started by discussing recommendations for changes to standard guidance as a result of the research gathered in this study. The next section was a collection of recommendations for programs that have similar characteristics to the SASSA program in size or pace for achieving a rapid acquisition.

F. SUMMARY OF FINDINGS

The completion of this study has yielded an assessment of the effectiveness of tailored SE processes on the SASSA program in achieving the cost, schedule, and technical goals in a rapid space acquisition. This study assessed six standard SE processes as tailored by the SASSA program. Of these six, one was judged as a neutral contribution while five were judged as helpful in achieving the program goals. No tailored processes were judged as negative contributions to meeting the rapid space acquisitions goals. These results are summarized in Table 1.

Modified SE Process	SASSA Modifications	Benefits	Risks	Contribution
Requirements Development	- No JCIDS process involvement/ utilization - No formal stakeholder involvement - No KPP/KPA's - Strong traceability from goals to req.'s	- Clear traceability from original goals to req.'s - Allowed program to move more quickly than a JCIDs program	- Potential lack of insight into final capability with no interim KPP/KPA assessment - Output capability of program not useful to	Positive

			users (potential)	
Modified SE Process	**SASSA Modifications**	**Benefits**	**Risks**	**Contribution**
Functional Architecture and Design Synthesis	- Gov imposed design aspects (TRL, HW units, heritage req.'s) - Defined Functional elements - Minimize inefficient/wasted design effort	- Focus program on likely solutions - High probability of plausible options	- Miss inventive or creative solutions - "Constrain out" better solution	Positive
Standard SE Plans	- No government or contractor SEP,SEMP, SEMS, or SEDS - Use of RFP, IMS, CDRLs for SE process - Program meetings to define processes - Use of Contractor processes	- Saved resources for Gov and contractor - Less documentation - Less overall tasks	- Gov does not see potential deficient SE plans of contractor - Gov is unclear on its own SE plans/process	Positive
Use of Systems Engineering Leads	- No dedicated SE lead on government team - Team SE process	- More than one SE - Diverse, collaborative SE tracking	- Lack of adequate SE - Inconsistent SE process - Critically dependant on team composition	Neutral
Technical Reviews	- SRR before IBR - Entry/Exit criteria not generated before program initiation - Criteria not in SEM(P) - No completely independent reviewers - No incremental reviews	- Superior knowledge of program requirements for baseline planning - Understand program needs from the start - Save resources - Thorough reviews	- Contractor not understanding tech event criteria in planning resources for baseline - Under scope resources - Too much in one review for larger programs - Miss independent perspective	Positive
Integrated Product Teams (IPT's)	- "Flat", versatile government team structure vice IPT structure	- More expertise exposed to more tasks - surge capability for quick task completion - Entire team up to date on critical issues - Counteracts stove piped thinking - Good fit for minimal Gov resources - Entire team aware of program status	- Too much information for all to absorb as program grows - Lack of ability to have needed depth in focused area in large programs - Lack of consistent follow through/tracking of single segment issues	Positive

Table 1. Summary of Tailored Standard Systems Engineering Processes

These conclusions lead the researcher to have recommendations for the application of the study:

1. Recommendations for the Systems Engineering Community

- Perform a survey of SE guidance for military acquisitions and ensure there is comprehensive coverage of SE processes (as opposed to SE technical management).
    - Publish a Primer which points to or consolidates this “how to do SE in the military” for ease of use and proliferation
- Create a new SE guidance or append the present guidance which would instruct on how to practically implement and accomplish SE processes on non-formal/ non JCID’s programs
- Create a new SE guidance or append the present guidance for recommendations on how to tailor standard guidance for non-formal/ non JCID’s programs
    - Address the importance and relationship of the large number of small technology and acquisition efforts to the larger formal programs and JCIDS process. Good SE is needed even in these small programs to be efficient in technology maturation as it relates to larger programs
- Continue to instruct in basic SE application and build a strong foundational knowledge of accomplishing SE processes in SE students
    - Advocate for high levels of practical implementation instruction for doing SE in military programs at universities and especially in military higher education facilities

2. Recommendations for Accomplishing Rapid Space Acquisitions

- Observe and consider the positive contributions made on the SASSA program by tailoring standard SE guidance

- Tailor standard SE guidance and choose quality teams using “value added” as a prime criteria
- Ensure processes proposed are followed throughout acquisition regardless of if they were tailored or not
- Assemble teams that have experienced and SE knowledgeable personnel as a “non-negotiable”
- Ensure processes proposed are followed throughout acquisition, regardless of if they were tailored or not
- Provide strong SE leadership on the team

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II. SASSA: ORIGINS AND OVERVIEW OF THE SASSA PROGRAM

A. INTRODUCTION

Space capabilities are intrinsically woven into Americans' lives, both civilian and military. These include communication (e.g., DirecTV, XM Radio, global cell phone nets, global relay of communication/information), navigation, weather, environmental monitoring and earth science, and military/national missions (including ISR, missile warning, battle space awareness, and intelligence, just to name a few). We are highly reliant on our space assets as a nation. The 2006 U.S. National Space Policy underscores this by stating that "space is a vital national interest." The populating of space with U.S. technologies, and the application of those technologies, is essential for the prosperity of the U.S. and global economies. It links the globe and speeds the flow of information. It is becoming a growing critical aspect of many areas of our way of life and government. This will result in an increased stake in protecting our national security interests, intelligence, military uses, and conduct of U.S. diplomacy—ultimately to protecting lives and the environment.

This same space infrastructure is fragile. Space systems are increasingly vulnerable to a variety of natural and man-made threats: space weather and debris; radio frequency jamming; laser dazzling and blinding; kinetic intercept vehicles; and space mines are just a few examples. The U.S. has no robust Space Situational Awareness (SSA) capability to unambiguously distinguish between an attack on a satellite or a naturally caused anomaly, especially "in situ." The Commission to Assess National Security Space Management and Organization summarizes the theme with this statement:

> If the U.S. is to avoid a "Space Pearl Harbor" it needs to take seriously the possibility of an attack on U.S. space systems. The nation's leaders must assure that the vulnerability of the United States is reduced and that the consequences of a surprise attack on U.S. space assets are limited in their effects. (2001, January 11)

Various discussion and documents support this growing emphasis on the criticality of the SSA of our space assets. “Counterspace operations have defensive and offensive elements, both of which depend on robust space situation awareness.” (Gen John T. Jumper, Foreword to AFDD2-2.1, Counterspace Operations). The USSTRATCOM JCD for Space Control (28 Jul 06) states:

> SSA must enable timely and accurate resolution between attacks and anomalies affecting US capabilities, [and]…monitor, characterize, predict, and report on the space related environment…detect, process, and report space events….characterize, assess, and resolve anomalies/attacks on all space systems.

The Space System Attack ID & Characterization Capability MNS (27 Jun 00) relates needed capabilities by listing “2.a.(1) “Detect and report attacks on space systems”; 2.a.(2) “Identify and characterize attacking systems”; 2.a.(4) “Capabilities must be rapid, accurate, reliable and interoperable”

Our nation, moving rapidly forward in technological maturity must take time to address the combination of a growing reliance on space assets with the increasing vulnerability of those same assets. The Self-Awareness Space Situational Awareness (SASSA) program is one of a handful of Air Force space acquisitions programs that was created to start addressing these issues moving into the future.

B. THE SASSA TECHNOLOGY DEMONSTRATOR DESCRIPTION

1. Acquisition Strategy

The Space and Missile Systems Center (SMC) requires all programs to have an approved acquisition strategy. The approval process starts at the smallest program office element in the Squadron and filters up through the Group, Wing, and then Center approval chain processes (if the program is large enough). SASSA received its acquisition strategy approval on June 2008 and was required to get Center level approval.

In preparation for this milestone event, the SASSA program office initiated a series of activities including:

- Call for white papers for possible threat warning instruments
- SMC survey of available satellite secondary payload volume, mass, and power
- Survey of possible host vehicles in progress and their relative timelines for development
- Review of available satellite bus user guides
- Review of industry standard electrical data bus utilization
- Review of possible acquisition methods with pros and cons (e.g., Sole Source, Full and Open competition, University or UART)
- Financial and budget analysis
- Industry Day Briefing with individual company Q&A sessions for feedback

The synthesis of these activities led to a decision to pursue a full and open competition to develop space-qualified hardware for a one-year on-orbit demonstration. This included releasing an RFP and completing a source selection. Due to overwhelming industry feedback, the program office seized a unique opportunity and chose to award two contracts (Cost Plus Fixed Fee) out of the source selection instead of a single award. These two contract awards were envisioned to be in competition for the entire 24-month period of performance towards a final selection at flight hardware delivery. The winner of the competition was to be awarded the opportunity for integration onto a host satellite with an activation of an option for one year of on orbit operation to perform technology demonstrations with the selected hardware. To select the winner a Flight Selection Plan was developed which weighed various criteria including overall performance, cost, schedule, and verification against the program’s Technical Requirements Document (TRD).

2. Timeline and Milestones

Figure 1 depicts the relative durations of the SASSA technology demonstration, rapid space acquisition.

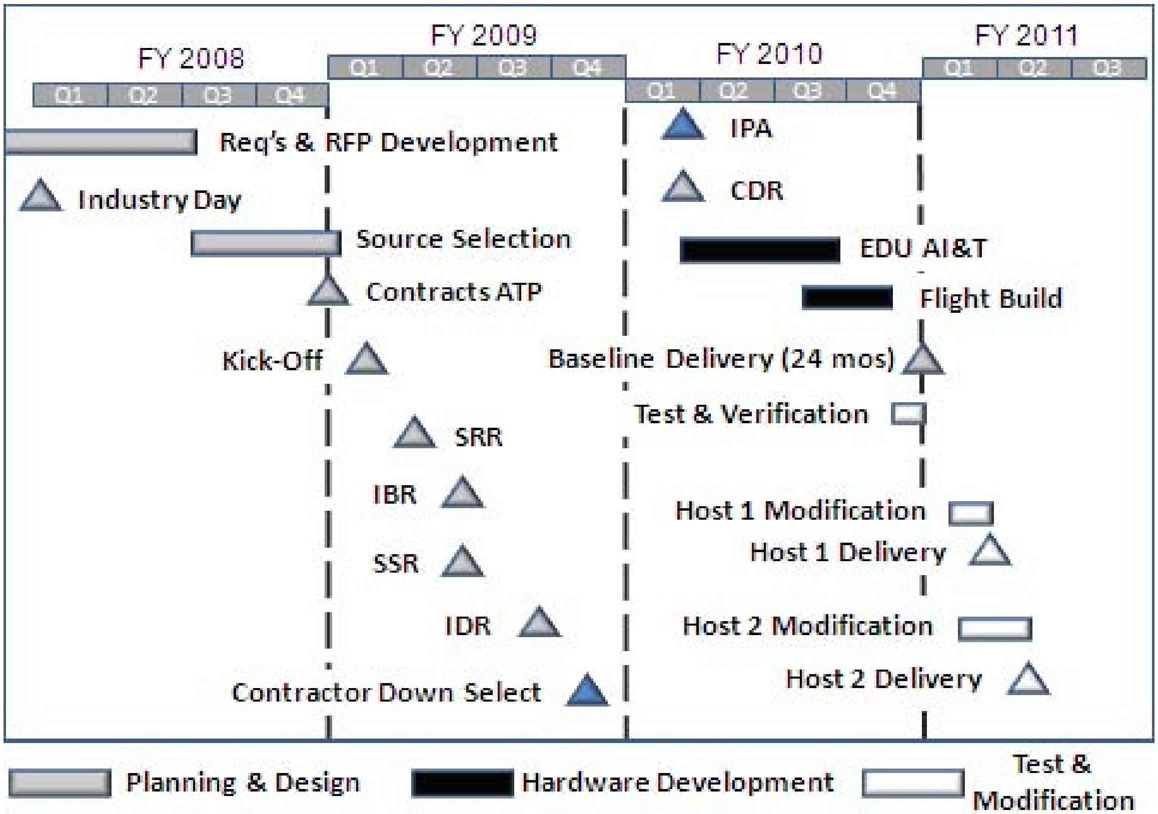

Figure 1. SASSA Program Timeline

3. System Description Overview

a. System Description

The SASSA technology demonstrator will consist of space, ground and test segments. The SASSA program leveraged mature and proven technologies and subsystems to demonstrate a viable threat warning architecture. It was designed to be minimally intrusive to the hosting satellite system (both space and ground segments.) The SASSA technology demonstrator space segment is designed to operate in low earth orbits (LEO) between 400 km and 1200 km.

b. Space Segment

The SASSA space segment consists of the common interface unit (CIU), two instruments—a radar warning receiver (RWR) and an independent dedicated satellite communication capability (DSC), an MCU-110 encryption/decryption device, the mounting structure, and all associated cabling/harness and software necessary to operate the SASSA payload. The CIU will provide the ability to support integration on heritage and new development spacecraft and facilitate integration of a wide range of threat warning instruments by providing a variety of current data interfaces. These include 1553, SpaceWire, or RS-422 for the host satellite interface and the same plus a compact preconfigured interface (cPCI) type for custom interfaces. The CIU also provides a single electrical power interface to the host vehicle, provides power distribution and control of instrument power, fault management, time & position services, data handling & control, and on-board data storage.

During mission operations, encrypted commands are received over one of two possible communications paths. The first path is via the host space vehicle interface. The second is via the dedicated stand-alone communications (DSC) instrument. Timed commands are decrypted and authenticated prior to executing the commands in the CIU. Mission data received from the instruments is formatted by the CIU into telemetry frames and encrypted prior to sending data back via either communication path. The CIU uses the MCU-110 encryptor to perform the telemetry stream encryption and command decryption from the host satellite data bus and NSA approved SGLS transponder for the DSC. Since the CIU is handling both encrypted and plain text data, the CIU has a security partition to maintain security isolation. One side of the CIU is responsible for interfacing to the host space vehicle and the other is responsible for interfacing to the instruments.

The instruments receive power, configuration commands, mission data files, timing, and ephemeris knowledge from the CIU. The instruments send health and status telemetry and mission data to the CIU. The health and status telemetry includes data collected by the CIU for analog temperature monitors, analog voltage monitors, and digital status telemetry.

The SASSA Space Segment mounts mechanically to the host satellite structure and receives thermal control, power, timing, position/velocity/ephemeris data, and passes encrypted command files sent from the SASSA ground. In return, the SASSA space segment provides the host space vehicle unencrypted telemetry of digital data collected by the CIU for analog temperature, voltage, and current monitors as well as encrypted mission data/ telemetry files.

c. Ground Segment

The SASSA ground segment provides command and control, mission planning, and processing/displaying of SASSA space segment information. This includes mission data analysis and display, archiving and trending, threat reporting, and aiding in anomaly resolution. The ground segment also can provide processed SASSA instrument data to external users by using the HTTP protocol and posting XML formatted data. The ground segment can interface to or reside inside the host satellite ground station. In either location, the SASSA ground segment can send and receive information from both the host satellite communication path or directly via the AFSCN network and the SASSA DSC instrument.

The SASSA ground segment consists of three subsystems. The Command, Control and Status Subsystem (CCS) provides the communication control to the host ground station or the AFSCN network. The CCS also provides for the execution of command plans and the health and status display and alerting. The second subsystem is the Mission Planning and analysis (MPA) subsystem. MPA performs the operations scheduling, SASSA instrument and payload resource deconfliction, and timed command and command plan generation. The Instrument Mission Data Analysis Subsystem performs the mission data and non-mission data packet processing, data analysis, trending, and reporting. The Instrument Mission Data Analysis Subsystem provides a Web-based HTTP interface for either browsing by SASSA users or a computer-to-computer interface using XML HTTP post.

d. Testbed

The SASSA Test Bed Segment refers to the SASSA test bed, which provides support prior to and after launch. The SASSA Test Bed, prior to launch, provides support to SASSA hardware and software development throughout the initial assembly level, unit level and system level design verification and acceptance test phases of the program. During this phase, the SASSA integration test bed provides a platform for both integration and test as well as verification and validation tasks. End-to-end testing is performed which includes instrument stimulation between SASSA and a host spacecraft computer simulator. Built in to the Test Bed is the capability to conduct end-to-end performance testing of the integrated SASSA space segment. After launch, the Test Bed provides the capability to aid with the anomaly resolution processes of on-orbit hardware. It may also be used for technology insertion evaluation of new and developmental threat warning sensors (instruments) and their compatibility with the SASSA system.

4. Program Summary and Current Status

The SASSA program received Authority to Proceed (ATP) in October of 2007, and held kick off meetings shortly after. Since ATP SASSA has conducted a Systems Requirements Review (SRR), Integrated Baseline Review (IBR), System Software Review (SSR), Interim Design Review (IDR), and Critical Design Review (CDR). In addition, it has also conducted an independent program assessment (IPA) at the suggestion of the SMC commander as well as a GAO audit. SASSA was a dual award contract and ran identical, simultaneous programs from ATP through IDR. The SASSA program achieved every milestone on schedule through CDR for the first contractor. The second contractor held all milestones on time except SRR, which was delayed by one month. The second contractor was terminated prior to IDR in order to retain funding obligations incurred when commitments were solidified with the first host satellite program.

The SASSA program currently has firm relationships with two separate satellites program organizations and plans to operate two complete SASSA systems. SASSA currently is maintaining its 24-month goal of delivering a complete baseline system including flight-qualified hardware. The baseline system is defined as a complete space segment, a ground segment, a Test Bed, and one set of EDU units of the CIU and RWR. The baseline system defines a basic flexible capability ready to be adapted to specific program needs. Deliveries planned in December 2010 and January 2011 will contain the SASSA baseline with specifically configured space and ground segments for each host. Delta CDR activities, to assess the maturity of the specific modifications needed to fly with each host, are planned to be held in the fall of 2010.

Leading up to the winter deliveries, the SASSA program has completed significant amounts of material to date. Two complete EDU space segments have been built with their respective unit software. Two complete ground segments and two complete test beds have also been completed. The first CIU flight unit is close to completion and starting unit test. The RWR flight unit is over 80% complete. The remainder of the fall will be spent completing environmental test and verification of system requirements. This will conclude the final build of space and ground software and as well as the completion and test of host specific modifications to the two units.

III. STANDARD SYSTEMS ENGINEERING PROCESSES DISCUSSION

A. INTRODUCTION

As the need for more refined systems and machines pressed the military over the last half century, the practices and standards across many disciplines for program management and engineering for acquiring these systems have been captured, defined and iterated. These standards at the industry, DoD and military branch levels for acquisitions attempt to define a standard roadmap for all military acquisitions for the purposes of producing the most effective product at the most reasonable cost. Refinement of these standards over time and innovation are critical to the continued success and optimization of effective systems for our modern military.

B. GENERAL SYSTEMS ENGINEERING PROCESSES

The discipline and specialization of systems engineering has firmly held one leg in the program management world and one in technical engineering. It has been an essential contributor to effective technical design process and to successful program management. Like broader acquisition guidance for specific engineering disciplines, systems engineering has also followed the path of formalizing its standards and processes to allow formal review and improvement. It is the review and improvement of these standards over a variety of program types that truly lends to the strength and adequacy of the standards by which our national assets are designed and fielded.

Attaining a concisely articulated working definition for systems engineering can prove to be difficult. Given the emphasis on standard guidance for systems engineering in this study, an adequate contextual, working definition of SE can be obtained by referring directly to the sources used for the study. Standard definitions of systems engineering are surveyed below and include:

DoD 5000.02: "Systems engineering provides the integrating technical processes to define and balance system performance, cost, schedule, and risk within a family-of-systems and systems-of-systems context." (p. 77)

Defense Acquisition Guidebook (DAG): "Systems engineering is an interdisciplinary approach encompassing the entire technical effort to evolve and verify an integrated and total life cycle balanced set of system, people, and process solutions that satisfy customer needs. Systems engineering is the integrating mechanism across the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal of, and user training for systems and their life cycle processes. Systems engineering develops technical information to support the program management decision-making process."(Adopted for DoD and derived from EIA/IS 632, DAG p. 159)

INCOSE SE Handbook: "Systems engineering is a perspective, a process, and a profession, as illustrated by these three representative definitions:

1) Systems engineering is a discipline that concentrates on the design and application of the whole (system) as distinct from the parts. It involves looking at a problem in its entirety, taking into account all the facets and all the variables and relating the social to the technical aspect. (Ramo1) 2) Systems engineering is an iterative process of top-down synthesis, development, and operation of a real-world system that satisfies, in a near optimal manner, the full range of requirements for the system. (Eisner2)

3) Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, and then proceeding with design synthesis and system validation while considering the complete problem: operations, cost and schedule, performance, training and support, test, manufacturing, and disposal. SE considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs. (INCOSE3)" (sec 2.2, p. 7)

Mil STD 499B:"An interdisciplinary approach encompassing the entire technical effort to evolve and verify an integrated and life-cycle balanced set of system people, product, and process solutions that satisfy customer needs. Systems engineering encompasses:

a. the technical efforts related to the development, manufacturing, verification, deployment, operations, support, disposal of, and user training for, system products and processes;

b. the definition and management of the system configuration;

c. the translation of the system definition into work breakdown structures; and

d. development of information for management decision making." (Appendix A, p. 40)

Aerospace Corporation Space Vehicle Systems Engineering Handbook TOR: "The goal of space vehicle SE is to ensure that a desired system is designed, built, and operated so that the system accomplishes its mission in the most cost-effective manner possible, considering performance, cost, and schedule risk." (SV SE – 1.1, p. 1) "System level SE is a process used to develop requirements and to integrate the technical efforts across a program." (2.2, p.17) "The essence of successful system engineering is to get all of the elements of a system integrated and working properly." (4.3.1., p. 69).

IEEE Std 1220-2005(ISO/IEC 26702): "The SEP is a generic problem-solving process that provides the mechanisms for identifying and evolving the product and process definitions of a system." (here, SEP is systems engineering process) (4.1, p. 12)

In summary, systems engineering provides the discipline in any acquisition program that works to understand clearly the motivating cause for the acquisitions, and then seeks to systematically achieve that end through the rigorous and consistent use of processes. In the most basic sense, SE attempts to be the guarantee that what is wanted is what is achieved. Or, as the SMC primer states, "SE is first and foremost responsible for ensuring that the 'right system' is developed to meet the customer's needs," while ensuring "that the ultimate system is 'developed right.'" (chapter 1, p. 38)

C. SPACE SYSTEMS ENGINEERING PROCESSES

Thus far, systems engineering has been addressed only in conceptual terms seeking a solid contextual working definition for this study. However, this study focuses on a particular field of Military and DoD acquisitions—that of space systems and SE with in this field. The Space and Missiles System (SMC) Systems Engineering Primer is a helpful guide in describing unique aspects for space systems and SE within this context:

> A satellite system is typically made up of one or more satellites (or space vehicles), terrestrial satellite control, and maintain elements, and user elements that permit the operational military forces to take advantage of the capabilities of the space system. Each satellite is made up of its elements, typically the payload (that provides the basic mission capability such as communications, surveillance, navigation, etc.) and the spacecraft or bus (that typically supports the payload by providing electrical power, thermal control, and attitude control, etc.). The payload and bus are, of course, subdivided into lower tier elements such as processors, sensors, communications (radios), and clocks which are in turn made up of parts (such as integrated circuits, relays, or roller bearings) and materials (such as metallic or composite structures), all fabricated and assembled using various processes. Similarly, a launch system is typically made up of the launch vehicles (which provide the initial boost toward orbit), upper or transfer orbit stages (which place the satellite in or near its operational orbit), ground control and monitoring systems, and facilities used for checking out, mating, and supporting the launch vehicles, upper stages, and satellites prior to launch. Each launch vehicle may be made up of multiple launch stages. Each launch stage and upper stage is typically made up of propulsion, guidance and control, and environmental protection elements. The distinction between launch systems and satellite systems is not always clear such as the case of the Space Shuttle which is a launch system that can also perform or support operations on orbit or the case of integral upper stages which are supplied as part of the satellite system to complete part or all of the transfer orbit function. (p. 2)

In addition to understanding terminology and what a space system consists of, it is also critical to understand the unique elements of designing satellites and vehicles for space in the SE process. The SMC SE primer highlights three main differences 1) the space environment, 2) unattended operation, and 3) the ultimate high ground. The space environment includes making design accommodation to operate in total vacuum, extreme temperature swings and ranges, operating in and through highly charged particles, as well as surviving “high vibration, acoustic, shock, and other environments during launch and deployment into the operational orbit.” (p. 3).

The second unique element is that, with the exception of the space shuttle and space station, all other space systems operate unmanned. This adds an additional complication for maintenance and problem resolution. As a result, space systems take advantage of redundant systems or reloadable software, highly reliable parts, added margin to performance and operational capability. The primer states, “Experience shows that the cost of these steps together with the cost of space launch is perhaps ten times or more the cost of comparable hardware deployed in terrestrial applications."(p. 3) This extreme premium on space hardware cost puts added pressure and importance on system trades "balancing the operational capability to be provided with other factors such as cost, reliability, and service life." (p. 3)

The final unique aspect of space is the concept of it being the final high ground. Conceptually, space provides the ultimate tactical and strategic advantage to arrayed military forces. As such, it is expected to and has the responsibility of interfacing a multitude of platforms. The SMC primer states:

> The user equipment for such systems can become deployed on a wide range of platforms and therefore rival or even exceed the cost of the satellites and launch vehicles so that the systems engineering task of balancing effectiveness and cost can be still more demanding and important. (p. 3)

The key point in this summary is that an increased emphasis and importance on wide system boundaries makes SE on space systems a complicated endeavor.

D. SYSTEMS ENGINEERING GUIDANCE CATEGORIES

In the evaluation of standard SE guidance sources, a distinction can be made, which separates SE guidance into two broad categories. The first category will be called SE processes. This category contains the day-to-day practical aspects of the SE process which systems engineers do as a part of the SE process "on the job." This contains both tasks, which are accomplished in more or less a serial fashion (assuming iterations) as well as those SE processes that occur throughout the SE process life cycle. These include serial tasks and processes such as defining customer needs, requirements analysis, functional decomposition, as well as processes like configuration management and risk management, which occur throughout the SE process. The second broad category of SE guidance is that which will be called SE technical management processes. This category of processes is more specific to military acquisitions and sits in the realm between program management and systems engineering. This contains guidance such as implementing SE plans (SEM, SEMP) and the use of integrated product teams as an organizational structure. DoD 5000.02, the DAG, the SV SE handbook, the SMC SE primer, and others all contain SE guidance for these types of technical management processes. The SASSA program tailored standard SE guidance from both categories in order to more successfully achieve a rapid space acquisition. Table 2 enumerates the broad spectrum of both categories of SE guidance.

Serial SE Processes (with iteration)	
1. Elicit customer desires/ needs	4. Design Synthesis
a. Interface and boundary identification (physical, logical, functional)	a. Create sequential build & test plan
b. Functionality identification and functional architecture development	b. Detailed interface management
c. Concept Refinement	5. Design Implementation
d. System architecture creation and representation	a. Hardware fabrication
e. Solution exploration and identification	b. Software Coding
f. Alternate System Concepts and Elements Definition	c. Technical data generation
g. Design Constraints Definition and Refinement	6. Analysis and Assessment
2. Requirements and Constraints Capture / Definition Analysis	a. System optimization
a. Performance requirements	b. Statistical analysis
b. Defining effectiveness measures	c. Reliability analysis
3. Allocation and Decomposition	d. Missions and Environments
a. Traceability	7. Verification and Validation of Requirements
b. Functional and Performance determination	8. Transition
c. Derived requirement generation	9. Operation Process
d. Hardware / Software allocation	10. Maintenance Process
e. System element allocation	11. Disposal Process
Parallel or Companion Processes Throughout the SE Process	
1. Configuration Management	6. Trade Studies
2. Quality and Mission success management	7. Modeling / Simulation
3. Requirements Management	8. SE tools / strategies application (i.e. Func Block Diag, Black Box, Func Flow Diag)
4. Risk Management and analysis	9. Weighted decision making processes
5. Specialty Engineering utilization and management	
SE Technical Management Processes	
1. Use of SEM/SEMP/SEMS/SEDS plans	7. Use of KPP/KPA and TPM's
2. Organizational Structure - IPT utilization	8. Modular Open Systems Approaches
4. Techncial / Capability Reviews	9. Long Term Data Managemetn strategies
5. SE Leads and Leadership	10 . Technical / Program Planning (use of WBS, IMS, IMP, EVMS)
6. Use of Competition	11. Program Protection and System Assurance

Table 2. Systems Engineering Processes for Acquisitions

E. BODY OF AUTHORITATIVE SOURCES FOR SYSTEMS ENGINEERING

This thesis sets out to, first, highlight a tailoring from accepted standard systems engineering processes and, second, to assess the relative merit and success of the tailoring towards the intended goal. The goal in this program is achieving a rapid acquisition of a satellite payload. In order to achieve the first objective, a standard from which to judge the deviation must be adopted and defined. Since the field of systems engineering is diverse, and its processes can be applied to programs of all sizes and objectives, it can be difficult to establish this "baseline" set of processes from which to draw distinction. This thesis will achieve this objective by defining a body of texts as relevant authoritative source material that are available to government and military organizations. For the purposes of this study, this body of material will provide the objective standard of SE processes from which distinctions will be drawn.

The set of material, which constitutes the relevant authoritative sources for this thesis, is found in Table 3.

Industry SE Standards
1. The International Council on Systems Engineering (INCOSE) Systems Engineering Handbook, v. 3.2, INCOSE-TP-2003-002-03.2, Jan 2010
2. ANSI/GEIA EIA-632, Processes for Engineering a System, 01 Sept 2003
3. EIA/IS 731.1, Systems Engineering Capability Model, Electronic Industries Alliance (Interim Standard), 01 Aug 2002
4. IEEE 1220-2005, IEEE Standard for Application and Management of the Systems Engineering Process, Institute of Electrical and Electronics Engineers, 09 Sept 2005
5. ISO/IEC 19760:2003 - A Guide for the Application of ISO/IEC 15288
DoD Acquisition Standards (with SE direction)
6. Defense Acquisition Guidebook (DAG) Feb 19 2010, chapter 4
7. Department of Defense DIRECTIVE NUMBER 5000.01 Nov 20 2007
8. Department of Defense INSTRUCTION NUMBER 5000.02 Dec 8 2008, Enclosure 12
9. Military Standard 499B May 6 1994
Space Acquisitions SE Standards
10. The Aerospace Corporation TOR-2006(8506)-4494, Space Vehicle Systems Engineering Handbook 31 Jan 2006
11. The SMC Systems Engineering Primer & Handbook, 3rd Ed, 29 Apr 2005

Table 3. Systems Engineering Guidance Sources

This set of sources was chosen for its ability to cover a broad range of application, for its ability to represent the view of the only professional SE accrediting organization, and for its ability to apply directly to the specific field of space acquisitions (including guidance from the center in which the SASSA acquisition was performed in, SMC).

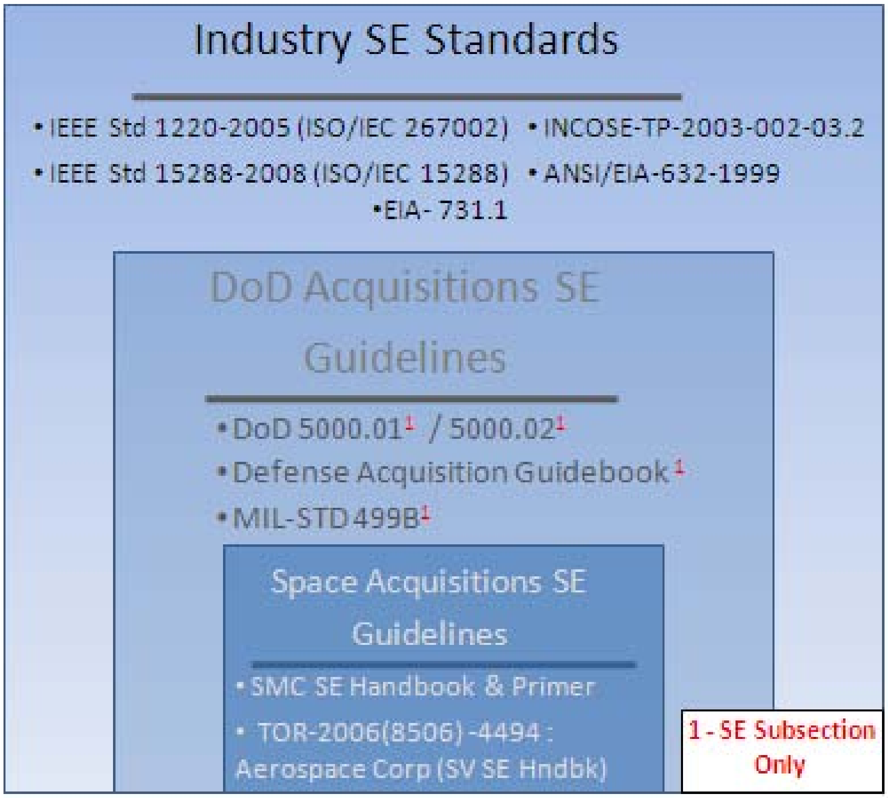

Figure 2. Relationship of Systems Engineering Guidance Sources

F. SUMMARY

The importance of standard guidelines for DoD acquisitions cannot be understated for maintaining efficient acquisition while producing quality products. A major undergirding of this guidance is the discipline of systems engineering. It is essential to maintaining our present military capability to produce acquisitions that replace, supplement, and advance our technological capability in securing and defending the freedoms this nation has. The process of applying these standards, tailoring them for varying acquisition needs, evaluating the results, and then capturing them to pass on to future programs, is an essential aspect to keeping our guidance up to date and relevant as acquisition philosophy changes over time. This chapter has created a context from which to evaluate the specific discipline of systems engineering. Specifically it has introduced the unique aspects of systems engineering for space systems. It has defined a reference set of material that defines standard SE practices for the purpose of this study. This in turn allows an evaluation of specific tailoring implementations.

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IV. DISCUSSION AND ANALYSIS OF APPLICABLE STANDARD SYSTEMS ENGINEERING PROCESSES

A. INTRODUCTION

1. SASSA Motivation for Tailoring Standard Systems Engineering Processes

The SASSA government program office accepted a difficult challenge upon contract award on October of 2008: deliver hardware ready for a space flight demonstration in 24 months. By comparison, it is typical to expect major acquisitions to range over three to seven years for complete space and ground systems. Smaller unit development or technology maturation projects often take at least 18 months and often are 24–36 months for flight ready hardware and software. In a surprising contrast, the SASSA program set out to deliver two complete systems, space and ground, in 24 months.

It was this challenging development timeline that drove the SASSA team to seriously challenge the status quo of SE practices and seek optimization. For the elements the program office had the ability to change, the SASSA team adopted a key paradigm: Executing standard process in a manner that is typically done on larger/longer space acquisition programs was *not* going to achieve success for the SASSA program. This paradigm manifested in a variety of ways including process optimization while maintaining SE discipline and rigor; focusing on substance and not simply process/format; executing processes that add value in the context of program objectives; relying upon the expertise of program individuals, as opposed to process; and looking for ways to efficiently execute/tailor SE processes. Therefore, it was incumbent on the SASSA program to determine the best changes in the execution of the program office and systems engineering elements. This fundamental view of space acquisitions, adopted by the SASSA program office team, was the cornerstone for modifying standard SE guidance.

2. Guidance for Tailoring from Standard Systems Engineering Sources

Most, if not all, of the authoritative SE sources address the topic of tailoring. Presumably, this tailoring is meant to keep the guidance being presented usable across a variety of types and sizes of programs. System engineers and program managers are called to constantly evaluate, modify, and adapt guidance to accomplish the overall goal—that of delivering the best system for the requirements on schedule and on cost.

Considering the source material directly aides in understanding the full intent for tailoring standard SE guidance. Chapter 8 of the INCOSE SE handbook states, "Oppressive overhead, with no visible value added contributions, is demoralizing, and may result in a system that costs more than it is worth." (p. 301). INCOSE also provides a notional (by their description) diagram aimed at visualizing the balance between too much and too little formality in SE. This formality refers here to the rigid application of standard guidance versus adapting guidance to different programs. Figure 3 displays Figure 8-1 from the INCOSE SE Handbook. The handbook goes on to explain saying:

> The principle behind tailoring is to establish an acceptable amount of process overhead committed to activities not otherwise directly related to the creation of the system. Tailoring scales the rigorous application of SE processes to an appropriate level based on need and the system life-cycle stage. (p. 301).

The Aerospace Corporations SV SE Handbook states similar content about how the SE processes "must be tailored to each specific program to reflect the scope, requirements, complexity, and phase of the program. Tailoring will define the scope of the SE process and the effort to be expended." (SV SE, p. 20). DoD instruction 5000.01 sec 4.3.1. defines tailoring in its description of "flexibility" with

> There is no one best way to structure an acquisition program to accomplish the objective of the Defense Acquisition System. MDAs and PMs shall tailor program strategies and oversight, including documentation of program information, acquisition phases, the timing and scope of decision reviews, and decision levels, to fit the particular conditions of that program, consistent with applicable laws and regulations and the time-sensitivity of the capability need. (p. 3)

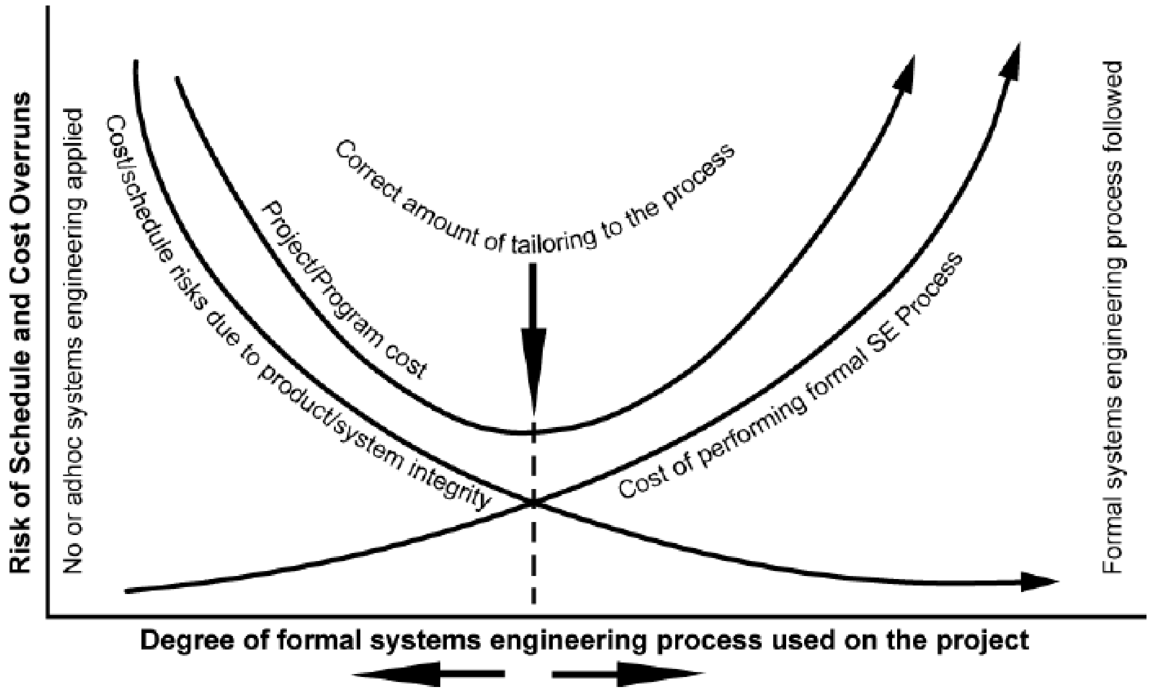

Figure 3. Tailoring SE Processes (INCOSE SE Handbook Figure 8-1)

It expands the thought in sec 4.3.3. with the description of "innovation" by saying:

> Throughout the Department of Defense, acquisition professionals shall continuously develop and implement initiatives to streamline and improve the Defense Acquisition System. MDAs and PMs shall examine and, as appropriate, adopt innovative practices (including best commercial practices and electronic business solutions) that reduce cycle time and cost, and encourage teamwork. (p. 3)

The DAG corroborates by saying,

> Although the system is based on centralized policies and principles, it allows for decentralized and streamlined execution of acquisition activities. This approach provides flexibility and encourages innovation, while maintaining strict emphasis on discipline and accountability. (p. 6)

These authoritative sources discuss the importance and necessity of tailoring SE processes for specific program with strong, philosophical statements. However, none of the guidance provides direction for practical implementation with criteria to use for tailoring. This leaves the SE community to rely on experience and judgment in determining the best way to tailor the standards.

3. Standard Systems Engineering Processes Chosen for Tailoring on SASSA

Upon the completion of source selection, the SASSA government team took time to reflect upon how best to execute the SASSA program. In this discussion various aspects of conventional program management and SE were highlighted and decisions were made as to how to best balance the needed SE rigor needed while enabling a rapid space acquisition. In a series of meetings it was decided which SE processes would be followed, which tailored, and which were not feasible to implement due to the program cost, timeline, resources or nature of the 24-month technology development program.

Of the larger set of processes listed in Table 2 in Chapter III D, six were chosen to be tailored for the SASSA program. Two of these six are SE processes and four are SE technical management processes (per the discussion in section III D). These processes were perceived at the time as being good candidates for tailoring to enable more efficient processes in achieving the SASSA rapid space acquisition. Table 4 lists these six processes, which were tailored for SASSA. Tables 5–7 list the standard SE processes from the authoritative SE guidance sources and identify how the SASSA program approached each process in following it, modifying it, or not implementing it. Chapter V assesses the tailoring for each of these six processes as implemented in the SASSA program for effectiveness in executing a rapid space acquisition.

SASSA Tailored SE Processes	SASSA Tailored SE Technical Management Guidance
1. Requirements Development	3. Standard SE Plans
2. Functional Architecture & Design Synthesis	4. SE Leads
	5. Technical Reviews
	6. IPT Team Structures

Table 4. The SASSA Tailored Standard Systems Engineering Processes

	Parallel or Companion Processes Throughout SE		
SASSA Implementation		SASSA Implementation	
I	1. Configuration Management	#1	6. Trade Studies
I	2. Quality and Mission success management	I	7. Modeling / Simulation
#1	3. Requirements Management	# 1, 2	8. SE tools / strategies application (i.e. Func Block Diag, Black Box, Func Flow Diag)
I	4. Risk Management and analysis	X	9. Weighted decision making processes
X	5. Specialty Engineering utilization and management		
# - SASSA Tailored Process ; I - Implemented Standard Process ; X - Utilized Development Contractor's Process			

Table 5. Systems Engineering Parallel Processes as Implemented in the SASSA Program

	Serial SE Processes (with iteration)		
SASSA Implementation		SASSA Implementation	
# 1	1. Elicit customer desires/ needs	# 2	4. Design Synthesis
	a. Interface and boundary identification (physical, logical, functional)		a. Create sequential build & test plan
	b. Functionality identification and functional architecture development		b. Detailed interface management
	c. Concept Refinement	I	5. Design Implementation
	d. System architecture creation and representation		a. Hardware fabrication
	e. Solution exploration and identification		b. Software Coding
	f. Alternate System Concepts and Elements Definition		c. Technical data generation
	g. Design Constraints Definition and Refinement	I	6. Analysis and Assessment
# 1	2. Requirements and Constraints Capture / Definition Analysis		a. System optimization
	a. Performance Requirements		b. Statistical analysis
	b. Defining effectiveness measures		c. Reliability analysis
#2	3. Allocation and Decomposition		d. Missions and Environments
	a. Traceability	I	7. Verification and Validation of Requirements
	b. Functional and Performance determination	X	8. Transition
	c. Derived requirement generation	X	9. Operation Process
	d. Hardware / Software allocation	X	10. Maintenance Process
	e. System element allocation	X	11. Disposal Process
# - SASSA Tailored Process ; I - Implemented Standard Process ; X - Utilized Development Contractor's Process			

Table 6. Systems Engineering Serial Processes as Implemented in the SASSA Program

	SE Technical Management Processes		
SASSA Implementation		SASSA Implementation	
# 3	1. Use of SEM/SEMP/SEMS/SEDS plans	# 1	7. Use of KPP/KPA/ TPM
# 6	2. Organizational Structure - IPT utilization	I	8. Modular Open Systems Approaches
# 5	4. Techncial / Capability Reviews	I	9. Long Term Data Managemetn strategies
# 4	5. SE leads and Leadership	I	10 . Technical / Program Planning (use of WBS, IMS, IMP, EVMS)
I	6. Use of Competition	I	11. Program Protection and System Assurance
# - SASSA Tailored Process ; I - Implemented Standard Process ; X - Utilized Development Contractor's Process			

Table 7. SE Technical Management Processes as Implemented in the SASSA Program

B. SASSA TAILORED STANDARD SYSTEMS ENGINEERING PROCESSES

The following sections describe where the SASSA program applied tailoring and modification in six specific system engineering process examples. Each section includes a discussion presenting the standard guidance as supported by the authoritative sources. This is followed by an explanation of what the SASSA program did to modify the standard guidance and what was actually implemented. Each section ends with a comparing and contrasting of the standard SE guidance, versus the tailored implemented process. The relative success of each tailored process is addressed in Chapter V, Section B.

1. Requirements Development

a. Description of Standard Requirements Development

The process of developing requirements is a fundamental discipline in the SE process. As such, there is a large amount of information available as SE guidance on this subject. The description here is not intended to be an exhaustive treatment of the subject, rather to provide an adequate summary description with references to guidance documents.

The SMC SE primer starts describing this process with the capabilities that a new system will provide. These new capabilities will come from one of two paths (typically): either technology "push" or capability or operational "pull." The "push" case involves a technology which has been developed and which is deemed useful by a stakeholder. The technology is judged worthwhile to pursue in greater development and implementation into a system for DoD use. For the "pull" case, there is a "top-down" operational desire or need for a capability levied. This need by the operational users needs to be met, and thus a technology development or acquisition is initiated to address the need.

These "pulled" or "pushed" capabilities and needs subsequently enter what is called the Joint Capabilities Integration and Development System (JCIDS) process for the Air Force. This is a series of prescribed and controlled process steps that major acquisition programs are required to follow. It is noteworthy that even non-major programs are recommended to use elements of the JCIDS process. Figure 4 is from the SMC SE primer (p. 7). This provides a summary overview of the JCIDS process. The following paragraphs summarize each step to provide an overview of the JCIDS process. Based upon a tremendous amount of system engineering effort, each step in the process produces either a trade study or a requirements document. As will be described, the ICD, CDD, and CPD are requirements documents with increased levels of system specificity.

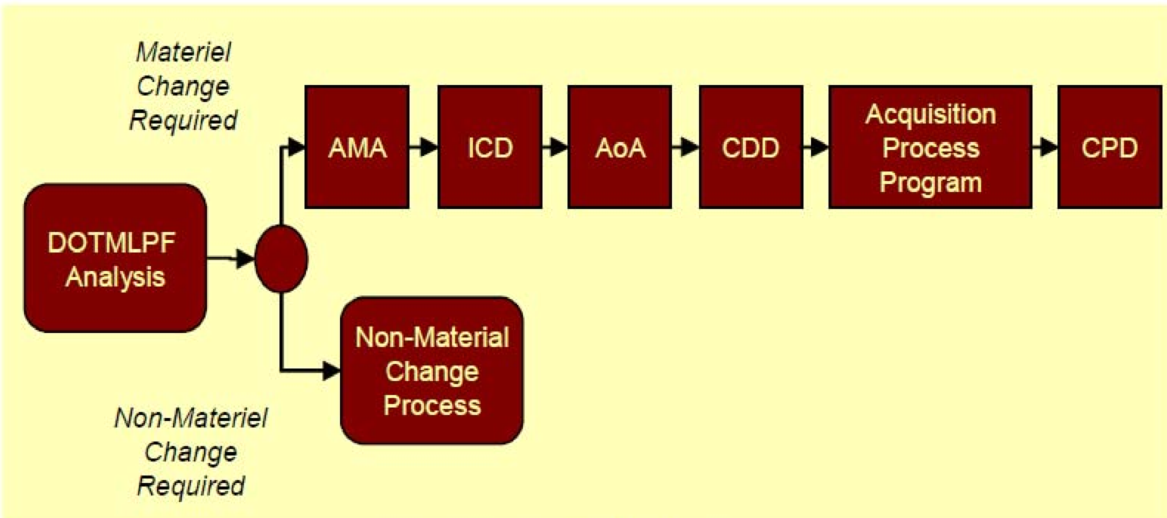

Figure 3. Key steps in the JCIDS process

Figure 4. JCIDS Process Overview (SMC SE Primer, p. 7)

The first step is a Doctrine, Organization, Training, Materiel, Leadership, Personnel, and Facilities (DOTMLPF) capabilities and deficiencies analysis. This analysis focuses on determining if a change in user methodology, doctrine, policy, or some other non-material means is sufficient to address the need. If an adequate solution cannot be determined then it is decided that something needs to be built to solve the problem. The main focus in this phase is to gate a decision as to whether a material change is necessary versus a process or non-material solution is adequate.

The second step is to complete an Analysis of Materiel Approaches (AMA). This process works to identify all the various means, implementations, and system approaches that may be utilized to meet the need or implement the technology. For example, "the AMA might focus on the preferred approach between a space-based, aircraft, or ship-based approach to provide a surveillance capability but usually would not identify the specific system concept to be developed." (SMC SE Primer, p. 6). It effectively creates the set of feasible options at a high level from which a group may choose to move forward with a solution or investigate critical technologies.

The third step is the creation of the Initial Capabilities Document (ICD). This is the formal capturing of the needs that are to be addressed by the acquisition activity and subsequent material products. It also captures the rationale for why a material solution was needed, as investigated in the DOTMLPF analysis.

The next step is to perform the Analysis of Alternatives, where the options presented in the AMA are evaluated and a recommended approach is decided upon. This may be an approach involving a single system in a single military branch or could be as expansive as a system of systems relying on multiple acquisition developments run in separate military branches of the government. At this stage, the JCIDS process initiates its references to milestones. After the AoA, is Milestone A. Milestone A has its own rigorous process to enter and exit, which can be found in a variety of DoD acquisition guidance documents.

The Capability Development Document (CDD) is the next step. The CDD captures the information necessary to develop a proposed program. Milestone B follows the completion of the CDD. This CDD builds on the information in the AMA, ICD, and AoA performed previously in preparation for Milestone A. At this stage in the JCIDS process, an emphasis is made to scope the increment or capability into achievable and affordable portions. The current paradigm, from the Defense Acquisition University, is "Evolutionary or Incremental Development," defined as "a desired capability is identified, an end-state requirement is known, and that requirement is met over time by developing several increments, each dependent on available mature technology" (Evolutionary Acquisition). The CDD supports the definition of these increments in the defining of the program that will execute.

The Capability Production Document (CPD) is the final step in the JCIDS process and supports Milestone C in the acquisition path. The SMC SE Primer describes the function of the CPD with "The CPD addresses the production attributes and quantities specific to a single increment of an acquisition program."(p. 42).

The SMC SE primer highlights how this guidance applies for major programs and non-major programs and how both are expected to utilize the various elements outlined:

> The JCIDS process just described will usually be applied to major programs (those with high projected cost or high-level interest). For non-major programs, the approach to defining the capability needs may be somewhat less formal, but will usually include documentation of the need in documents such as the ICD and CDD. (p.7)

With an overview of the entire JCIDS process in mind, it is beneficial to treat in greater detail where requirements development occurs and plays a key role in the larger framework. Within and between the CDD and CPD phases the development of program requirements start (SMC Primer, p. 42) (i.e., the development of requirements from which the space system can be designed, built, tested, and ultimately operated to satisfy a mission need). It is at this stage of the requirements development process that the JCIDS acquisition process references other industry and DoD standards/guidance sources for requirements development since this stage involves a broader process to all SE rather than just how the DoD accomplishes their acquisitions.

ANSI/EIA 632 helps identify the start of this broader requirements development process, which is stakeholder involvement. ANSI/EIA 632 requirement #4 a) states "Identify stakeholders who will have an interest or stake in the outcome of the project." (pp. 10–11). Similarly, Requirement 15 a) and b) state "a) Identify and collect other stakeholder requirements that can constrain the system's end products. b) Identify and collect other stakeholder requirements that can constrain development, production, test, deployment/installation, training, support/maintenance, and disposal of system end products." (p. 21). Where ANSI/EIA 632 is an international industry SE process, the DAG helps corroborate the expectation of stakeholder involvement within the DoD JCIDS process direction. The DAG states,

> The program manager and systems engineer will work with the user to establish and refine operational needs, attributes, performance parameters, and constraints that flow from JCIDS described capabilities, and then ensure that all relevant requirements and design considerations are addressed (DAG, 4.2.3.2.1. p. 172)

To accomplish this stakeholder input and requirements development process within the larger JCIDS framework, DoD SE guidance recommends using the DoD Architecture Framework (DoDAF). This framework utilizes Key Performance Parameters (KPP) and Key System Attributes (KSA) concepts for eliciting stakeholder needs and desires. The DoDAF defines a common approach for DoD architecture description development, presentation, and integration for both war fighting operations and business operations and processes (DAG 4.2.3.2.1. p. 199). KPPs and KSAs may be policy mandatory requirements pushed down by the military chain of command such as "Net Ready" or "Sustainment," or may be just the capturing and articulating of end metrics, which help focus the program on a desired outcome. ANSI/ EIA 632 supports this in Requirement 5 f) stating "Identify technical performance measures that will be used to determine the success of the system, or portion thereof, and that will receive management focus and be tracked using Technical Performance Measurement (TPM) procedures." (p. 12). A more detailed definition of the function and purpose of TPMs, KPPs, and KPAs is provided in a note by ANSI/EIA 632:

> NOTE—A TPM program provides an early warning of the adequacy of a design in terms of satisfying selected critical performance parameter requirements of a system end product. TPM also examines marginal cost benefit of performance in excess of requirements. A *critical performance parameter* is one that characterizes a significant total system qualifier. In addition, it must be possible to project the evolution of the parameter as a function of time toward the desired value at the completion of development. The projection can be based on verification, validation, planning, or historical data. (p. 12)

The completion of this often-lengthy requirements process for the government is the creation of the Technical Requirements Document (TRD). The KPPs, KPAs and other stakeholder inputs are captured in formal program requirements in the TRD. This TRD forms the system requirements basis for DoD solicitation for procurement. Based upon the TRD, the development contractor usually creates the System Specification. The Technical Requirements Documents (TRD) and the System Specification are the two documents that capture the total requirements for a program (SMC SE Primer p. 7; SV SE Handbook, p. 657). The system specification then forms the basis for the System Requirements Review (SRR) where all parties and stakeholders concur that an accurate understanding of the program requirements has been captured in the system specification. The validation of the System Specification and thus the TRD for a program should satisfy the KPPs and KPAs for the specific increment defined by the CDD and CPD. The measured ability to satisfy these high-level documents allows the next increment to be initiated in the overall JCID's process.

b. SASSA Tailored Requirements Development as Implemented

To fully understand how the SASSA program completed requirements development the acquisition source of the SASSA program should be considered. The SASSA program was initiated by Congress assigning funding to demonstrate a concept for providing Space Situational Awareness (SSA) threat warning capability on a satellite. In order to accomplish this quickly, the JCID's process was not used. At this stage, there were no major stakeholders, only a defined desire for an increased technological application. Those on the SASSA team took their knowledge of SSA current issues, previous programs, and long-term planning roadmaps as inputs to the shaping of the program. The only input at the start of the program was the wording provided in the Air Force unfunded request to Congress:

> The recent test (01/11/07) of the Chinese anti-satellite weapon (ASAT) demonstrated the most visible aspects of the growing counterspace efforts around the world which would exploit the heavy U.S. dependence on space assets and services. SASSA provides the sensing capability for current and future space high-value assets to detect and attribute interference or attacks. These capabilities are crucial to enabling a full

> range of U.S. responses, from diplomatic to military, in the event of hostile action against our spacecraft. (FY08 Air Force Unfunded Request Language, Courtesy of SAF/USA)

Without formal stakeholder requirements, and short timeline, the SASSA program had to decide how to generate requirements. The SASSA team attempted to focus the technology demonstrator objectives on key near-term enabling technologies. Thus, in lieu of actual stakeholder inputs, the SASSA team generated the closest it could approximate given the larger SSA picture and incorporating that into what could be done within the SASSA rapid space acquisition timeframe.

The next step in the SASSA TRD requirements-generation process was to create a set of program functional objectives (Table 8, TRD 2008) that would focus the technology demonstration and synthesize all the data that the SASSA team had analyzed regarding mission needs, operational utility, constraints imposed by existing and future satellite systems, as well as current technology state. Following the creation of the program functional objectives, the government then created the technical requirements document (TRD) for the SASSA program. The SASSA team ensured that each TRD requirement could be traced back to at least one of the eight functional program objectives. This was viewed as essential to show how the program developed progressively from its core objectives.

Program Functional Objectives	
R1	**Interface with multiple common spacecraft busses** - Use standard and common interfaces (hardware, electrical, data)
R2	**Accept integration of multiple dissimilar instruments** - Use standard and common interfaces (hardware, electrical, data)
R3	**Use a modular and scalable software architecture**
R4	**Build/modify and integrate multiple high TRL threat warning instruments**
R5	**Output sensor information in an easily accessible format**
R6	**Meet the Minotaur & EELV launch Vehicle families**
R7	**Build a test bed to verify interface compatibility and functionality through end-to-end testing**
R8	**Integrate an independent communication capability**

Table 8. SASSA Functional Objectives

The final phase in the SASSA requirements development was the transition of the government TRD requirements into the contractor system specification and sub-level specifications. This was accomplished once the government obtained a SASSA development contractor. The SASSA contractor developed a draft system specification that provided a working basis for the System Requirements Review (SRR). At this review, each TRD and system-level requirement in the system specification was discussed in detail for understanding. Each requirement's adequateness and appropriateness was assessed.

In the requirements development process of the SASSA program there were a few conscientious decisions made to enable greater efficiency in achieving success in the rapid acquisition. These were first, the use of a minimal set of functional technical requirements in the TRD (which defined the core SASSA capabilities required); second, the use of an Excel-based traceability tool; and third, the development of a SASSA interface control document.

The SASSA government team attempted to address multiple issues in creating a minimal functional TRD. The first was that the program simply did not have large amounts of time to engage in a TRD process that similar or larger programs in SMC would go through. Capturing the essential elements in performance and function in as few requirements as possible was thought to streamline this process. A minimum number of requirements also gave SASSA the advantage of less overall overhead in dealing with requirements management. By SASSA consolidating the number of requirements down to a minimum, it also enabled the contractor maximum room for implementation, which was a good best practice for SE in problem solving. This was thought to enable the maximum amount of flexibility in the implementation of the system as well, which was in line with the overall objectives of the SASSA system. The result was a SASSA TRD with just over 40 requirements (TRD, 2008).

Another implementation the SASSA team utilized was that of a traceability matrix in Microsoft Excel. The SASSA program put a significant emphasis in the SE activity of requirements decomposition, flow-down, and traceability processes. The standard software, called Distributed Object Oriented Requirements System

(DOORS) (Babcock, 2009), presented hurdles in efficiency, which the SASSA team sought to overcome. Namely, these were portability, user friendliness, and ability to have an end-to-end perspective of the requirements across the system. (It must be noted that the SASSA development contractor used DOORS to perform their requirements management; they tended to utilize the Microsoft Excel product produced from the DOORS database in working situations.)

The solution for SASSA was a single spreadsheet using a combination of rows and columns in hierarchical order to capture requirement numbers and requirement text, and how that requirement was decomposed and allocated to subsequent specifications. Figure 5 shows an example. Each government input document (e.g., SOO, SOW, TRD, CONOP) is allocated a section of rows with a break between documents. Each document's section lists its input requirements in successive rows listing the requirement number and language, as labeled in columns above these sections. Following each requirement in the next row down and in the adjacent column was the decomposed requirements in the next set of documents in succession. The order started with government input documents, then the System Specification, Segment Specifications, Unit Specifications and finally SRSs. Each subsequent column relates the requirements created (derived) as a result of the higher parent requirement in the earlier row and column. The resulting matrix, albeit large, allows a reader to work in detail, requirement by requirement, to see how a particular requirement is being decomposed and addressed through lower-level derived requirements. The use of this matrix was expanded to capture performance values of certain requirements as well as verification information such as type of test, the location of the test in manufacturing and assembly, and the expected verification products.

	TRD Requirement Flowdown			
Customer TRD Requirement ID	**Customer TRD Requirement Text**	**Sys Spec Requirement ID**	**Sys Spec Requirement Text**	**Segment Spec Requirement ID**
1010	SASSA shall have two instruments: Instrument One is the Radar Warning Receiver (RWR); Instrument Two is the Dedicated Stand-alone Communication (DSC) system.			
		SS_21	SASSA shall have two instruments: Instrument One is the Radar Warning Receiver (RWR); Instrument Two is the Dedicated Stand-alone Communication (DSC) system.	
				SP_1
1020	SASSA shall be available 80% of the experimental period after the flight system completes on orbit checkout.			
		SS_4	The CIU shall perform Power-Up Built In Test (PBIT).	
		SS_7	Each powered instrument shall perform PBIT.	
		SS_8	Each instrument shall report PBIT results to the CIU	
				SP_174
		SS_95	The SASSA system shall be capable of withstanding exposure to any combination of the Table 3-3, "Transportation and Handling Environments", including transportation by air and/or over-the-road, with no degradation in performance.	

Figure 5. Example of SASSA Excel Traceability Spreadsheet

In its final form, the matrix allowed a user to look at a single requirement and assess its completeness of decomposition across the specifications of the program to the resulting design elements: how each requirement was assessed in meeting the performance aspects of the requirement, and how and where the requirement was going to be verified in the testing phase of the program. The fact that the matrix is in Microsoft Excel means that it is easily manipulated in software that is almost universally available on all computer systems. Having the actual language of all the requirements in a traceable chain, and having all the requirements easily identifiable and filterable, makes the matrix exceptionally useful and easy to navigate. This became a great asset for thorough review and efficiency in performing rigorous SE on the program.

Another unique SASSA program requirements development activity was the development of the SASSA three-volume set of interface control documents called the Standard Interface Specifications (SIS). These were developed by the SASSA program in looking forward to activity beyond the technology demonstration. Specifically they were developed with a goal for follow-on activity in future instantiations of SASSA programs as well as a method to capture lessons learned on the SASSA program. The SASSA program conceived that for SASSA to be effective into the future that two items needed to be addressed. The first was that the variety of threat warning instruments needed to be expanded to be effective. The second was that host satellite organizations needed to know what to expect if the SASSA concept was really to be proliferated. The SIS volumes were conceived and written to address these needs.

SIS Volume I is written for the instrument provider who is interested in building a SASSA compatible instrument. Recall an “instrument” is any device that enables threat warning. This was coined to get out of the trap of thinking that threat warning is simply about having a sensor or sensors. The instrument concept includes threat-warning sensors, but allows for capability enhancers or force multiplying enabling technologies to be included. This includes, for example, concepts like a battery backup in case primary bus power is lost. SIS volume one was written to be a “one-stop-shop” for the instrument vendor who wanted to get into the threat warning instrument field and become a SASSA compatible instrument. SIS volumes II and III are written for the host satellite programs. Volume II describes the interfaces between the SASSA CIU and the host space vehicle. Volume III describes the interface between the SASSA ground segment and the host ground. The combined set was an attempt at first exposure to an organization that either was interested in having a SASSA system or had been directed to be compatible with a SASSA system. Each volume discusses the pertinent information each respective space and ground system would need to understand about the SASSA hardware, software, procedures, and planning methodologies. This could bring the organization a considerable way before interacting with the SASSA team directly and facilitate much more efficient conversation.

c. Comparison of Standard Systems Engineering Guidance to SASSA

The first and most significant deviation from standard SE guidance was that it did not participate in any form of the JCIDS process. SASSA did not follow this guidance to utilize an ICD or a CDD in its requirement generation process.

The second major deviation was the choice to move forward without stakeholder input acquired by standard (JCIDS process) or other means. A plausible argument could be posited that SASSA would have had more value if stakeholder inputs from the Air Force MAJCOM requirement offices and operational users were garnered before moving forward with any type of hardware development. The SASSA team considered this. It determined the process of gathering this feedback could easily consume the majority of the 24-month timeline for the effort. Therefore, the SASSA team chose to move forward with a spaceflight demonstration and utilize as much input as could be obtained in the process. Ultimately, the majority of inputs were from those who had worked in previous organizations of interest or generated by the SASSA team. SASSA decided that flying a technology demonstrator would be more valuable at eliciting stakeholder input and involvement than spending the money entirely on attempting to garner support and stakeholder buy-in.

The third aspect where SASSA deviated from standard SE guidance was in not identifying particular KPPs, KPAs, or TPMs for the program as recommended. A KPP/KPA/TPM is identified as attempting to "provide an early warning of the adequacy of a design in terms of satisfying selected critical performance parameter requirements of a system end product." (ANSI/EIA 632, p. 12). This function was not explicitly defined for SASSA in the form of KPP/KPA/TPMs, rather SASSA judged each of the TRD requirements as tier one or tier two (TRD, 2008). All the tier one requirements were deemed to be essential to the success of the SASSA program and were watched closely and specifically assessed at every major milestone review. It should be noted that the SASSA program did regularly status particular key requirements in monthly reviews and referred to them as TPMs. Despite having the same name, the SASSA TPMs and those highlighted as KPPs or KPAs in the standard SE guidance did not accomplish the same function.

2. Functional Architecture and Design Synthesis

a. Description of Functional Architecture and Design Synthesis

The functional architecture and design synthesis process in SE occurs after the requirements definition and allocation steps have been completed. The “functional architecture” here may refer specifically in the larger DoD acquisition as what is developed and utilized in the JCIDs process and in conjunction with the AMA and AOA process steps. This phrase may also be used in the more general SE process steps as an element of the SE process in moving from specific requirements to design elements. This study is referring to the later of these two in this section.

The SMC SE Primer describes this process in the broader context of the other SE processes depicted in Figures 6 and 7 (pp. 44, 46).

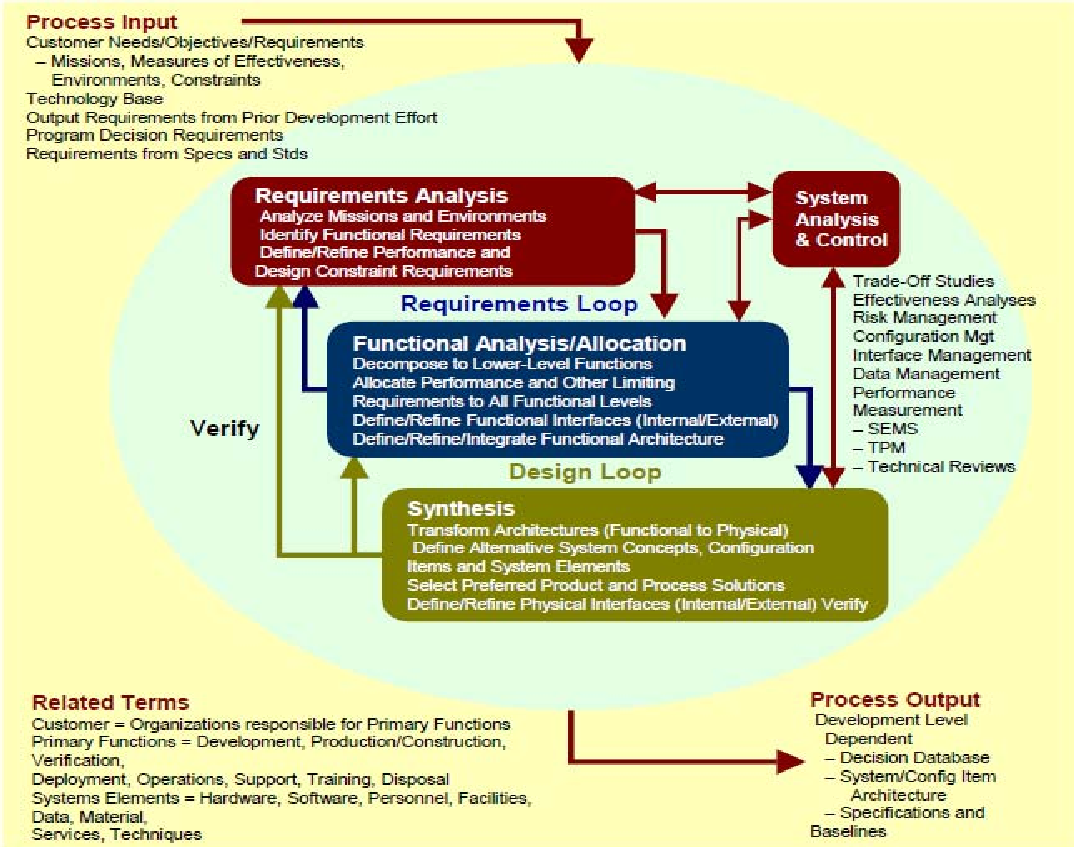

Figure 6. Simplified SE Process (from Figure 13 SMC SE Primer)

Specifically, The SMC Primer provides working definitions for the Functional Architecture and Synthesis steps:

> The functional architecture defines how the functions will operate together to perform the system mission(s). Generally, more than one architecture can satisfy the requirements. Usually each architecture and its set of associated allocated requirements have different cost, schedule, performance, and risk implications. (p. 49)

> Synthesis is the process whereby the functional architectures and their associated requirements are translated into physical architectures and one or more physical sets of hardware, software and personnel solutions. (p. 50)

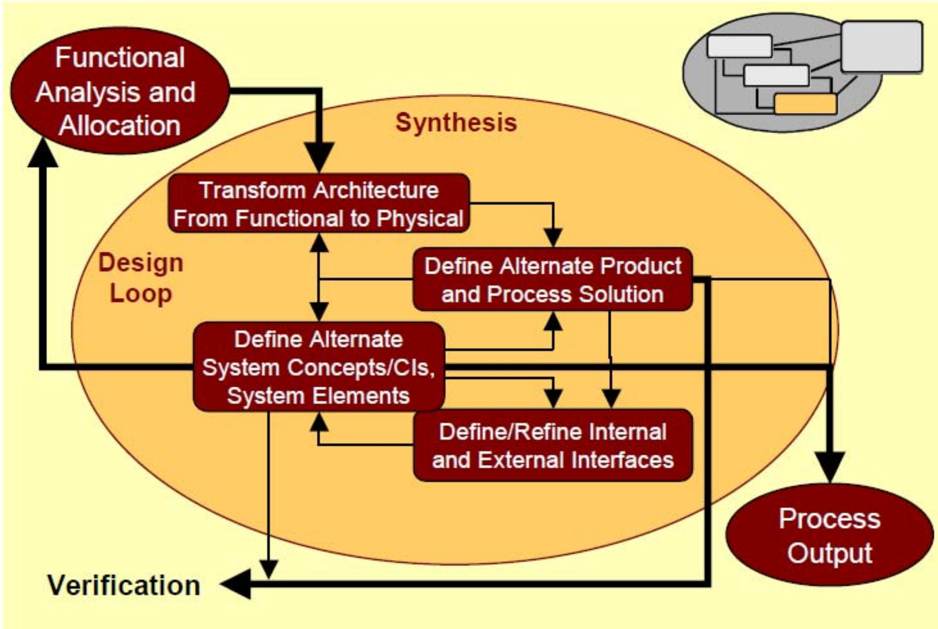

Figure 7. Requirements Analysis Process (SMC SE Primer Figure 14)

These two steps taken together result in the translating of particular requirements, represented as needed functions that are grouped logically, into a physical design. This is often the aspect of design and engineering that is most often looked forward to or jumped into prematurely. If followed rigorously to this point, ideally the SE process will have avoided preconceived physical implementations of requirements and functional allocations. It is in this stage where design is conceived to meet sets of needed functions that in turn are then represented as physical designs. The implementation of this design can lead to commercial off the shelf (COTS) usages or identified needs for modified, new, or state-of-the-art hardware that does not exist.

A related and essential aspect of this phase is the identification of the internal and external interfaces. Up to this point in the SE process, there will only have been requirements and functions identified. As these functions are logically grouped, the early identification of interfaces can take shape. The internal interfaces may represent interfaces between functions within a particular grouping of functions, or between logical groupings of functions. External interfaces are those that are those at the boundaries of the system and groupings of functions. As the SE process is advanced, these internal and external interfaces take on specific form and detail. These may be functional, procedural or have physical aspects such as power, data, or timing signals. The goal of the synthesis section in producing an approved design implementation that meets the needed functions is to also to have identified all the interfaces, internal and external, and their respective detailed information.

During this functional architecture and design synthesis phase, it is recommended that multiple alternatives be carried in parallel. These alternatives represent different cost, risk, and performance implementations, and are utilized as a method of risk management. These various implementations allow the program a "back-up" should the higher-performance (or primary) solution prove infeasible, too costly, or require too lengthy of a development schedule (SMC SE Primer, p. 49). As a design trade exercise, a program will assess all the alternatives and choose a primary path to be developed. The other paths can remain in a less mature state until there are signs that they many need to be developed and implemented as a risk reduction strategy.

b. SASSA Tailored Functional Architecture Design and Synthesis as Implemented

The SASSA program made certain decisions early in the program planning stages, which directly shaped the functional architecture and design synthesis phase for the contractor. In the simplest terms, the government office performed early stages of the functional architecture and synthesis design process. This resulted in requirements for the potential offerors to propose to in the RFP. The steps that the government office took were first to translate the congressional language into broad objectives. The second phase was to generate various possible design implementations by creating reference architectures. This process also served a secondary purpose in aiding cost estimation for program budget planning. This trade space of reference architectures was generalized into various potential mechanical hardware implementations and then converted back into a functional block diagram formats as an attempt to encourage creativity to solve the problem but within certain mechanical constraints.

The process of generating possible design implementations and creating reference architectures occurred in the program after the SASSA program was notified that it was likely to receive funding. This task was conducted internal to the Air Force SMC Wing organization, and in collaboration with the government personnel and contracted support personnel. This scope of the short analysis of alternative type study was to determine the best and most useful combinations of technology demonstrations between ground and flight options, and what aspects of the system should be placed in priority over others. It also set out to determine what types of sensors to make a priority in the SSA threat warning suite since it was likely to be cost constrained.

This was useful, first, in defining the boundaries of the SASSA system for the possible range of solutions. It was also helpful in defining likely interfaces for the system. This sense of interfaces and solution boundaries helped determining feasible and infeasible architecture solutions for consideration. The less feasible solutions would likely require higher levels of technology maturity or development risk. The more feasible solutions would require less risk and could be developed more quickly. This study also helped identify realistic expectations for technical capability ranges. This included sensor capabilities for various threats, realistic views of orbit ranges, and a better understanding of the size, weight, and power of such systems in space. This combined sense of what was possible with an associated risk provided useful data as a context for deciding the best method of program execution and building a feasible plan in schedule and budget for meeting the rapid space acquisition.

The output of this study period was what ultimately led to the modification of the design and synthesis SE process for the SASSA program. It was determined that in order to achieve the rapid acquisition in the allotted time aspects of the design synthesis and SASSA technology demonstrator needed to be constrained. The end result was a set of required segments, a set of required functions specific to each segment, and a set of required mechanical hardware unit implementations specific to the space segment.

A final aspect of SASSA’s implementation of the functional architecture design and synthesis process was the decision to utilize high heritage and high technical readiness level (TRL) hardware. This included the constraint of NSA type one approved encryption and decryption capability. All units had to have some heritage relationship and were required to be at TRL six or above, or to have a government-approved TRL maturity plan approved. This decision was made in an effort to meet the rapid 24-month schedule with flight ready hardware ready for a space flight demonstration. Overall, this constraint limited the total possible solutions, but allowed for lower risk designs that had a basis in previous efforts.

c. Comparison of Standard Guidance to SASSA

In this instance the difference between standard SE guidance and what the SASSA program implemented is more subjective than previous categories. This has to do with where one draws the line between a legitimate constraint in the SE development process and a strict interpretation of the Prephase A concept generation phase. If a strict interpretation (or more purist SE approach) is taken then there really should be no constraints on the system except those strictly necessary to address the needed capabilities and functions. This creates an extremely open trade space, which encourages creative problem solving with innovative solutions. At some point, legitimate options in the trade space in this open style SE approach will be weeded out due to realism being added back into the system. Less feasible and unrealistic solutions will then not be pursued in the military acquisition—as appealing as those envisioned capabilities may be.

If this view of SE is adopted and used to judge against what the SASSA program implemented, it would have deviated greatly. This would have constrained many aspects of the possible design space in the very early phases by interpreting the congressional language into reference designs. To be more in line with the SE guidance the SASSA program should have left the contractor much more trade space to consider design options as long as they could justify that they were meeting the intent of the direction and/or higher level objectives decomposed from the congressional language.

The SASSA program could also be judged against a more liberal interpretation of the SE guidance. This view may allow greater constraints to be imposed earlier in the SE process, thereby constraining the possible set of feasible designs, justified as an aspect of meeting the overall goal of the SE process. In this interpretation, SASSA would not be judged to have deviated greatly. SASSA would be viewed compliant for having provided functional requirements and objectives. They may have been judged as having deviated from guidance by provided aspects of the design by segment or even dictating specific implementations for the CIU, RWR, and DSC instruments.

3. Standard Systems Engineering Plans

a. Description of Standard Systems Engineering Plans

Standard systems engineering plans is the term designated in this study to refer to the family of similar documents described in systems engineering guidance, which address a standard description of how systems engineering will be accomplished in an acquisition. Typically developed in the early stages of an acquisition, it can include all of the following: the Systems Engineering Plan (SEP), the Systems Engineering Management Plan (SEMP), the Systems Engineering Master Schedule (SEMS), and the Systems Engineering Detailed Schedule (SEDS).

MIL-STD-499B section 4.1, titled "Systems Engineering Planning Implementation," provides requirements for the developing of and implementations of systems engineering plans stating, "The integrated technical effort shall be reflected in the Systems Engineering Management Plan (SEMP), the Systems Engineering Master Schedule (SEMS), and the Systems Engineering Detailed Schedule (SEDS)" (p. 9). It goes on to describe how the government should write and provide the SEMP as contractual direction where the "performing activity" (i.e., the contractor) should execute, maintain, and update the SEMP (p.9). It also describes how the contractor should be tasked to develop the Systems Engineering Master Schedule (SEMS), and the Systems Engineering Detailed Schedule (SEDS).

The Space Vehicle SE Handbook provides similar direction in sections 2.2.2.7 titled "Government Systems Engineering Plan," and 2.2.2.8. titled "Government Development Plan." This handbook states, "The purpose of a government SEP (or its equivalent) is to organize government teams' roles, accountabilities, and products." (p. 29). It also addressed other plans by saying that "…it is necessary to have a systems engineering master schedule (SEMS) or the equivalent" (p. 9).

The Defense Acquisition Guidebook corroborates this direction in section 4.2.2. stating,

> Best practice is to align the government SEP with the contractor's SEP/SEMP/technical plan following contract award and maintain alignment and currency. Where practical, these documents should initiate a process to unify the program technical planning between government and contractor(s) (p. 175).

It is helpful at this point to understand the general topics and themes covered in a SEP and SEMP in order to gain a context for understanding how SASSA's tailored SE processes addressed the same topics or themes. The SEP is the government's systems engineering plan while the SEMP is the contractors system engineering management plan.

Appendix C1 of the SMC SE Primer provides an example SEP outline. A sampling of key topics is captured in Table 9.

• Systems Engineering Organization	• Technical Reviews
• Certification Requirements	• Configuration Management
• Configuration Management	• Technical Baseline Management
• Systems Safety	• Data Management
• Systems Engineering Tools	• Interface Management
• Verification and Validation	• SE and Management Tools
• Security	• Program Integration
• Specialty Engineering	• Contract Management
• Resource Allocation	• Work Breakdown Structure

Table 9. Sample SEP topics

Appendix C1 of the SMC SE Primer also provides an example SEMP outline. A sampling of key topics is captured in Table 10.

• Systems Engineering Process	• Systems Analysis and Control
• Requirements Analysis	• Risk Management
• Functional Analysis and Allocation	• Configuration Management
• Synthesis	• Interface Management
• Technical Performance Measurements	• Data Management
• Technical Reviews and Audits	• Specifications
• Configuration baselines	• Verification Planning
• Systems Engineering Tools	

Table 10. Sample SEMP topics

b. SASSA Tailored Systems Engineering Plans as Implemented

The SASSA government team used a series of processes and tools to define and determine its SE approach for the SASSA program, as well as its expectations for the contractors. The first was technical meetings, discussing the SE approach to be used for the government team and what should be required of the contractor. This discussion covered various levels of formality and responsibility for boards (e.g., configuration management, part selection, failure review, risk management). This included discussion of what various SE elements on the program should be under governmental control. It was consensus from these discussions that the SASSA team moved into the second major process, the preparing of the RFP for the source selection.

The drafting process for the RFP continued to align and solidify the views of the government members as well as capture the consensus in the source-selection evaluation criteria. Multiple sections of the evaluation criteria required the contractor to provide justification of their SE processes. This provided criteria from which to judge the SE capability and processes of the offerors (SASSA contractors). It also solidified the government team's approach and expectations for the contractor for SE processes. A beneficial side effect was a configuration-controlled (via source-selection process) assessment of each contractor's SE approach and plan. The government team had the opportunity to evaluate the potential offeror's responses to these process requirements, and ask questions of the contractor—to make sure they clearly understood the ability and intent of the contractor in doing SE on the SASSA program.

The next tool the SASSA team used was the integrated master schedule (IMS). This defined for the program major SE functional tasks and phases, as well as other required contractual deliveries. The government also used contractual deliveries in the form of Contract Data Item Deliverables, known as CDRLs. Examples of CDRLs chosen to aid in understanding the contracts SE process and plans include a government-approved software development plan (SDP), configuration management plan, and a parts management plan (PMP).

Once the SASSA program was initiated and running, the program utilized other processes to augment the SE process already captured. The SASSA program office utilized a combination of government-only processes, as well as contractor-led processes. The government-led processes included engineering review boards (ERBs), change control boards (CCBs), requirement analysis, and approval. These particular processes were chosen by the government because they represented key nodes in the SE process at the government level. Issues raised to these process levels needed to be controlled at the government level due to their potential for significant shifts in the program requirements, design capability, or overall performance.

The SASSA program also made use of the established contractor corporate processes for risk management, trade studies, configuration management (CM), requirements allocation and verification, and failure review boards (FRBs). Additionally, the contractor proposed the use of their command media SEMP as an already established practice. This benefited the program without having to expend time or resources in writing one for the SASSA program. These particular processes were chosen because they were good candidates to run efficiently at the contractor level. They were already in contractor "format" and, as such, were easy and efficient to implement. These processes instilled adequate SE process checks at the developer level, without adding significant overhead or resource drain to the contractor.

Overall, the SASSA program implemented a wide variety of smaller, easy-to-implement processes that took advantage of the natural progression of the program in order to define, communicate, and execute the plan for doing systems engineering. These processes utilized a combination of pre-contract award, government-run, and contractor-run processes, and represented the complete SASSA approach for executing systems engineering on this rapid acquisition.

c. Comparison of Standard Guidance to SASSA

The SASSA team did not follow SE guidance for creating a SEP, SEMS, and/or SEDS. Rather, the team adapted a series of other tools and processes. The SASSA team decided to try to keep the program as streamlined and efficient as possible, minimizing the required overhead to the bare minimum, while still achieving the necessary insight for implementing SE on the SASSA program. This "light and lean" approach consisted of a variety of individual elements taken as a whole for how SE would be implemented on the program.

These elements consisted of 1) the RFP evaluation criteria for processes for systems engineering and software engineering management—this captured in a configuration-controlled format—the government's expectations for SE implementation on the SASSA program; 2) the contractor's proposal response to the RFP for these criteria—this articulated the contractor's process and plan without requiring a standard SEMP or similar documentation; 3) the integrated master schedule (IMS)—this captured major SE milestones and task phases and their interrelations to other critical events; 4) the required contractual deliveries (CDRLs) that are government approved for CM, PMP, and the SDP—this provided governmental influence on critical detail elements of SE implemented on the program.

The complete combination of these elements allowed the SASSA team to save resources and time for both the government team and contractor teams, while still achieving a necessary understanding and agreement for how SE would be implemented on the SASSA program.

4. Use of Systems Engineering Leads

a. Description of Systems Engineering Leads From Guidance

The directed use of systems engineering leads is discussed primarily in the Defense Acquisition Guide (DAG), but is also included in DoD 5000.02, which the DAG references and then expands on. The major direction from SE guidance is to appoint a systems engineering lead for a program. Both DoD 5000.02 and the DAG talk to this aspect:

> Each PEO, or equivalent, shall have a lead or chief systems engineer on his or her staff responsible to the PEO for the application of systems engineering across the PEO's portfolio of programs. The PEO lead or chief systems engineer shall: a. Review assigned programs' SEPs and oversee their implementation b. Assess the performance of subordinate lead or chief systems engineers assigned to individual programs in conjunction with the PEO and PM. (5000.02, p.77)

> This technical authority should ensure not only proper systems engineering process application to programs but also to proper training, qualification and oversight of systems engineering personnel assigned to programs. As part of this overall responsibility for technical oversight, the technical authority should: Nominate a lead or chief systems engineer to the program manager at the initial stages of program formulation. The lead or chief systems engineer should be accountable to the program manager for meeting program objectives, and accountable to the systems engineering technical authority for the proper application of systems engineering. (DAG, p. 173)

Guidance is straightforward in its intent for each program following it to assign a systems engineering lead for each program. It is then this individual's responsibility to oversee and ensure the implementation of the proper application of systems engineering for meeting the program objectives. According to 5000.02 and the DAG, there should be an assigned SE lead for every program.

b. SASSA Tailored Systems Engineering Leads as Implemented

The SE function for the SASSA program was performed as any of the other tasks that needed to take place on the SASSA program. Chapter IV, B 6, will discuss this application in light of IPT structures on the SASSA program. In the interim, it is important to understand that there was no IPT structure on the SASSA government program. SE tasks were assigned/allocated to the individual best able to work the task. As a result, SE for the program was done in a team fashion, with individual elements being worked by individuals approved and iterated by the consensus of the group. The results of the task(s) were presented to the larger team and defacto brought to consensus given peer review. The task lead acted as the issue lead, and the Air Force officer in charge approved the final product for the program.

c. Comparison of Standard Guidance to SASSA

The primary deviation from standard SE guidance and the SASSA program as implemented was that SASSA did not appoint or use a SE lead for the SASSA program. There was no single person assigned the responsibility for ensuing what SE processes were followed or ensuring they were accomplished. The SASSA program took a simplified approach with a much flatter organizational structure. This structure basically had a single lead with a group of people without titles, who all participated to make the SASSA program a success. Each program task was delegated a lead, which matured the task to a level where the rest of the team could provide feedback. The SE for the program followed the same pattern. To date, there is no single SE lead in charge of the SE aspect of the government team. This implementation can sound very counterproductive towards the goal of accomplishing excellent SE. This indeed is a risk for every team adopting this method. However, the SASSA team considered this and weighed the abilities of the small team and their ability to work together, and, by mutual consent with the approval of the program lead, made the decision to implement the approach.

5. Technical Reviews

a. Description of Technical Reviews From Guidance

Technical reviews are major milestones in the life of a program. These are typically used as approval gates for forward progress. Technical review milestones most often follow the same order and have a prescribed content per standard SE guidance. The

SMC SE Primer describes them as “requirements reviews, design reviews, and configuration audits” and describes that they:

> Provide an opportunity to assess program status in considerable detail. In particular, requirements and design reviews can be essential to monitoring at points in the program prior to the availability of test and other verification data that provide a direct indication of contract compliance. (p. 89).

The milestones that are commonly part of an acquisition are summarized, in order of occurrence, in Table 11, taken from section 1.5 of the Aerospace SV SE handbook, which is consistent with the DAG.

Integrated Baseline Review (IBR)
Objective: Obtain agreement between the program office and contractor on the five risk areas: technical, schedule, cost, resource, and management processes.
Occurs: As soon as practical after the contract award, and following every KDP thereafter.
Key Outcome: Agree on a plan of action to handle the identified risks.

System Requirements Review (SRR)
Objective: Review requirements and requirement flow-down.
Occurs: Approximately twelve months after contract go-ahead.
Key Outcome: Freeze system requirements and establish a functional baseline design.

System Design Review (SDR)
Objective: Contractor establishes the system baseline design, allocates requirements to the segment level, and ensures verification planning is adequate at the system and segment levels.
Occurs: When design has proceeded to the point where requirements have been allocated to elements.
Key Outcome: Establish a system design specification baseline.

Preliminary Design Review (PDR)
Objective: Establish a preliminary baseline design for every CI.
Occurs: Within eighteen months of SRR completion. A PDR shall be conducted for each CI and one for the system.
Key Outcome: Establish a "design-to" CI baseline.

Critical Design Review (CDR)
Objective: Final review of baseline design before manufacturing.
Occurs: Within eighteen months of PDR completion. A CDR shall be conducted for each CI and one for the system.
Key Outcome: Freeze design changes, establish a "build-to" for all CIs, and start manufacturing configured items.

Table 11. List of Program Milestones (SV SE Handbook, p. 8)

Standard SE guidance from the SV SE handbook goes on to describe that two of these reviews, PDR and CDR, are each not to be conducted as single review rather “are a summary of progressive or incremental reviews that start with specific configuration items (CI’s), then assemblies or subsystems, and culminate in a system-level review.” (SV SE Handbook, sec 2.4.1.3, p. 40). This is corroborated by the DAG sec 4.3.3.4.2. in saying,

> For complex systems, a CDR may be conducted for each subsystem and logistics element. These incremental reviews lead to an overall system CDR. Incremental design reviews are usually defined at Interface Control Document boundaries. (p. 240)

Standard SE Guidance provides more direction for technical reviews regarding when the program has the technical review, as well as the means by which the program judges the criteria and readiness of the program for a particular review. DoD instruction 5000.02, in the Technical Reviews section states:

> Technical reviews of program progress shall be event-driven and conducted when the system under development meets the review entrance criteria as documented in the SEP. They shall include participation by subject matter experts who are independent of the program (i.e., peer review), unless specifically waived by the SEP approval authority as documented in the SEP. (p. 77).

It is important for this study to highlight three main aspects from this SE direction. The first is that technical reviews shall be event driven (as opposed to schedule driven) and follow the order set forth in guidance. The second that entrance and exit criteria are used and are defined previously in the SEP, or at least identified prior to the beginning of the program (ANSI/EIA 632 Req 5 g, p. 12). Thirdly, that there should be participation by subject matter experts who are independent of the program.

The DAG shows its support of these same points by quoting DoD 5000.02 directly then expanding on the themes in section 4.3 (p. 208). As well as corroborating the direction given in DoD 5000.02, the DAG makes an additional recommendation regarding technical reviews. Section 4.3 states “To assist in the preparation for and conduct of technical reviews technical review risk assessment checklists are available for each of the reviews." (209). These "checklists" are a recommended approach for defining the content of each of the reviews as well as a tool to assess the completeness of the review.

Note: Guidance from the DAG is intended in the context of a major program of record (JCIDS). The DAG makes reference to significant lead times necessary to prepare for these significant events and how material developed in pre-acquisition may be needed to be used as inputs in this material (sec 4.3, p. 209). This reference is clearly made in the paradigm of a major A, B & C Milestone event type program. An assumption was made in applying SE direction for accomplishing a major program milestone such as PDR or CDR to a similar event held for a pre-acquisition type technology demonstrator like SASSA. It was viewed as applicable in the sense that, when a program holds a major event like CDR, there are only a few sources that can be used as examples to provide a template for what the event should be like and the content it should have, albeit used as a starting place for tailoring. If this type of guidance was not used due to its inapplicability, and if taken in the strictest sense, then there would be no guidance available for a SASSA-type program's milestone event.

b. SASSA Tailored Technical Reviews as Implemented

The SASSA program identified its major and minor sets of program milestones to be accomplished in the Integrated Master Plan (IMP), as identified in sec 6.2.5, Attachment CD4 to the SASSA RFP. Milestones are identified as either an Event (E) or a Significant Accomplishment (SA). The list of Events is listed in Table 12 and the list of Significant Accomplishments is listed in Table 13.

1.	SASSA Integrated Baseline Review (IBR)
2.	SASSA System Requirements Review (SRR)
3.	SASSA System Interim Design Review (IDR)
4.	SASSA System Critical Design Review (CDR)
5.	SASSA Pre-ship to SV Host Review
6.	System and Segment On-orbit Test Completion Review

Table 12. SASSA Events (SASSA RFP Attachment CD-4, p. 36)

(NOTE: The IDR event is very similar to a PDR cited in SE guidance.)

1.	SASSA Kick-off Meeting
2.	SASSA Testbed Design Review
3.	SASSA Software Specification Review (SSR)
4.	SASSA Testbed Certification (TC)
5.	SASSA AI&T Start
6.	SASSA Mission Readiness Review (MRR)
7.	Support to SV Host Flight Readiness Review (FRR)
8.	Support to SV Host Launch Readiness Review (LRR)
9.	Support to SASSA Launch

Table 13. SASSA Significant Accomplishments (SASSA RFP Attachment CD-4, p. 36)

Directly after contract award the SASSA program made a decision on the order that the milestones would be conducted. The order that the milestones were executed is listed in Table 14 with (E) for Standard Event and (SA) for a Significant accomplishment.

1.	SASSA Kick-off Meeting (SA)
2.	SASSA System Requirements Review (SRR) (E)
3.	SASSA Integrated Baseline Review (IBR) (E)
4.	SASSA Software Specification Review (SSR) (SA)
5.	SASSA System Interim Design Review (IDR) (E)
6.	SASSA System Critical Design Review (CDR) (E)

Table 14. SASSA Milestones Conducted

After the initial Kick-off meeting with each contractor, the SASSA program decided to accomplish the SRR first followed by the IBR, despite the traditional reversed order. The next milestone in order following the IBR was the IDR (Interim Design Review), which acted as a progress review between SRR and CDR in place of a PDR.

Each of the cited standard SE documents provides guidance on using major milestones in order to assess maturity before proceeding to the next major phase of an acquisition. SE guidance also directs when and where milestone entry and exit criteria should be generated and content checklists for each event. Aside from these examples, however, there is no other instruction for the execution of the events. In order to prevent major schedule setbacks due to inadequate maturity at the milestone reviews, it was imperative that the correct material be provided and reviewed efficiently. Thus, the SASSA program developed a methodology out of this need to emphasize program momentum in order to maintain cost and schedule goals for the 24-month delivery.

The first aspect of the SASSA process was to create and expose the contractor to the milestone entry and exit criteria for the event. The SASSA program developed its own entry / exit criteria tailored from standard guidance sources such as MIL-STD 1540, MIL-STD 499B, and MILSTD 2167. The government team created them prior to each event (8-12 weeks out) and discussed them with the contractor. The next step was to set up a review schedule leading up to the event. A goal for this was to provide a means to review the material for content and presentation, judging it against the entry criteria for a sufficient level of maturity. The SASSA team decided to require final presentation-quality briefing materials and supporting data 30 days prior to the event.

Once material was received, the SASSA team followed an aggressive internal review process designed to assess the quality, clarity, completeness, and maturity of the material. A series of iterative cycles occurred where the government team shared their findings with the contractor and subsequent corrected material was provided. Figure 8 depicts this process over the 30-day review cycle.

Approximately two weeks prior to the event, a meeting was held to discuss the readiness of the contractor to conduct the review. This meeting was commonly referred to as the “Go/No Go” meeting. If sufficient maturity was achieved against the criteria, then the contractor was contacted in the following days to share with them the entry criteria grading. If the maturity of the material was insufficient, the milestone would be delayed with specific areas to be addressed. The government team would work issues in a “shoulder-to-shoulder”-style working meeting in the following days.

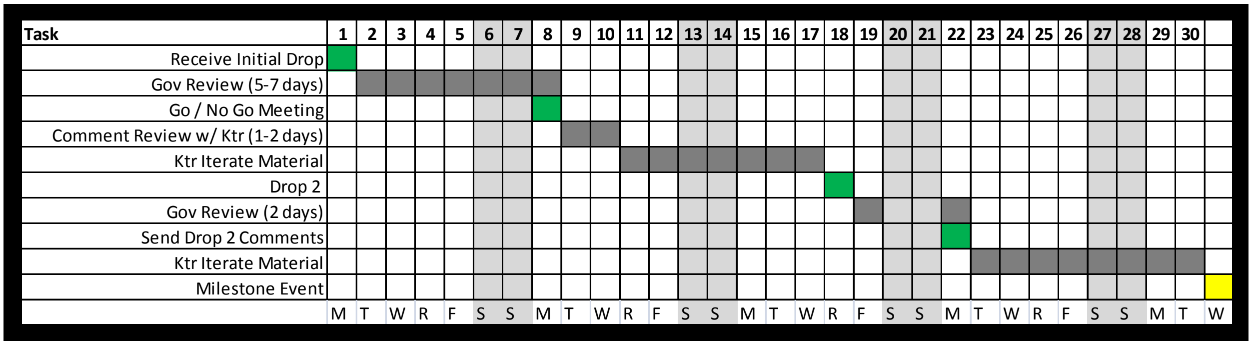

Figure 8. Example SASSA Milestone Review Schedule

The end result of this iterative process was a good screening for maturity and major issues early. This minimized the possibility that there were major surprises discovered at the event, which could cause significant schedule delays. This also left a moderate amount of time to work questions and issues prior to the event so that, going into the event, the majority of these were resolved. The strategy adopted was to do the majority of the work prior to the event so that the event itself could be focused on the summary of all the material as a wrap-up and culminating event vice the start of the review process.

At the conclusion of the milestone event, the government team would caucus and build an out-brief presentation given on the last day of the meeting. It would consist of a recap of the entry criteria grading and would highlight any areas of concern. It would then provide a grading against the exit criteria and recap any significant issues and action items captured. This presentation would be briefed by the government, typically the SASSA program manager, to the program management team of the contractor. This extra effort by the government team was extremely well received by the contractor. This process provided immediate feedback, which was very rewarding to the contractor.

The milestone event process concluded with "action items" being captured from the event and the government team requiring the contractor to provide an action-item closure plan for each action. Since major issues would have kept the event from occurring, these actions were typically not major program or technical issues.

Occasionally a significant issue would be "discovered" in the course of the event review and would need to be adjudicated in short order. When these action item closure plans were provided, the government would officially close the event.

c. Comparison of Standard Guidance to SASSA

The first and most apparent deviation the SASSA program took was to conduct the System Requirements Review (SRR) as the first major event. A typical order, following standard SE direction, a program would hold post Kick-off is IBR. This is normally due to the fact that the IBR establishes the "baseline" of resources allocated to tasks, schedule, and the overall implementation of the program budget. It is often viewed as necessary to accomplish this event before anything else. The SASSA team knew that an IBR needed to be conducted quickly. However, given the extremely intense development schedule of only 24 months, the most beneficial task to be accomplished first was for all organizations to agree on the requirements of the program. Not only was this viewed as an important place to start the program with the contractors, it was viewed as a beneficial input to the developing of the baseline for IBR.

The second deviation SASSA implemented was two-fold. The first was the choice to generate the technical milestone entry and exit criteria within the team, rather than simply use the milestone event checklists available in the standard SE guidance texts. The second was to develop the criteria 8-12 weeks before the event rather than before the program started and formalize it in a SEP type document. This was obviously in part because the SASSA program did not have a standard SEMP or SEP. However, every effort was made to consult current industry best practices and standard SE guidance checklists for milestone content and criteria as inputs from which SASSA entry and exit criteria were tailored.

The next deviation SASSA made was regarding participation by subject matter experts who are independent of the program. SASSA did not accomplish this in a strict sense where a completely independent team is brought in to assess a design review or technical milestone. Rather, SASSA did rely on the Aerospace Corporation "matrix" personnel. These are FFRDC technical experts in various fields who can be hired by the government team to assess the maturity of a particular area. SASSA also invited members of organizations who showed interest in the SASSA program from various locations within the military to participate in major reviews. SASSA made routine use of these experts throughout the program in all major design reviews. These personnel then acted as pseudo independent (attended repeated events) evaluation sources as the same people for certain niche fields would be brought in but who did not work the program in a day-to-day manner.

The final modification that SASSA made from standard SE guidance was to *not* adopt the systematic, incremental build up of lower level units or segments into a system level technical milestone event (PDR & CDR). For example, in the SASSA structure for IDR (SASSA's PDR like event), this would have looked like a mini-PDR or technical review at each of the unit levels (CIU, RWR, MCU-110, Ground Units, etc), followed by a segment-level PDR review for Space, Ground, and Testbed, all culminating in a System PDR. While standard SE guidance and good design practice (especially for large programs), this approach was viewed as an extremely time- and resource-intensive approach. For SASSA, the benefits did not outweigh the costs to the program, which would likely have put meeting the 24-month schedule at significant risk.

6. Integrated Product Team (IPT) Structures

a. Description of Integrated Product Teams (IPT) in Standard SE Sources

A very common and pervasive standard SE guidance, including in space acquisitions at SMC, is the use of Integrated Product Teams or IPTs. One source describes the genesis of IPTs by saying:

> IPTs evolved as a response to "stove-piped" engineering organizations in which producibility or reliability specialists, as examples, might NOT be integrated into the design activity with the result that the associated constraints might be given inadequate attention or "band-aided" late in the development with a resultant lack of balance in the design." (SMC SE Primer, p. 35)

IPTs form organizations into functional or logical groups for the purposes of better cross-organizational communication. Government program-management teams and contractor teams alike are almost exclusively arranged or are required to be arranged in an IPT structure. Each IPT in this structure has a government and contractor lead. These IPTs can be very formalized, with a charter, schedule, and deliverables between IPTs; or they can be very informal, put together for a short period to address a specific issue or problem (as in the use of "tiger teams"). Figure 9 illustrates the SMC SE Primer's example of a generic IPT implementation (Figure 46. IPT Typical Organizational Structure, p.149)

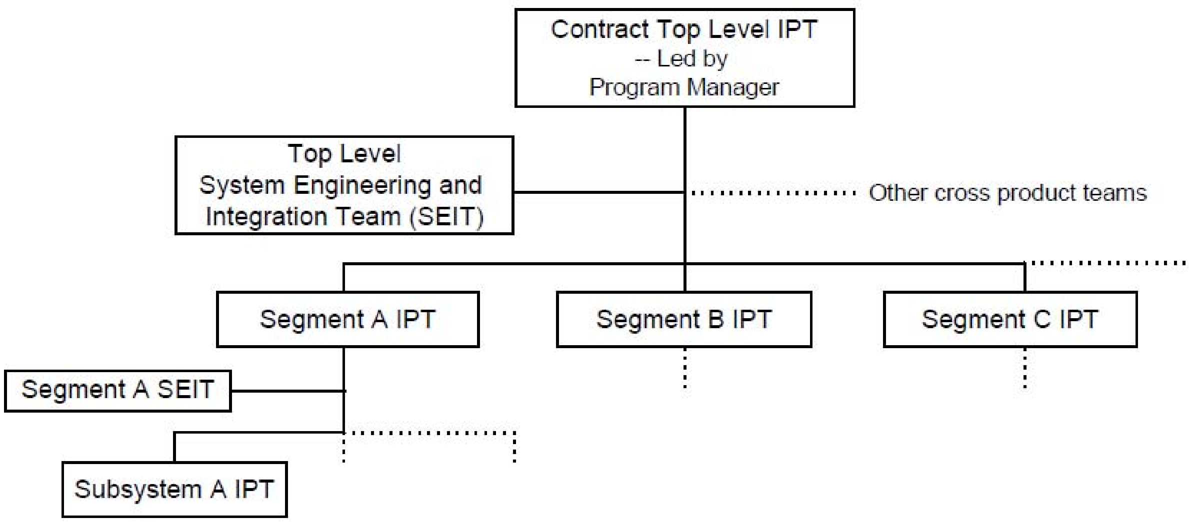

Figure 9. Typical Organizational Structure

Direction for use of IPTs in SE guidance texts is pervasive. The INCOSE SE handbook (p. 185–195), discusses at length the historical transition from development done in series (one task accomplished before the next) to IPTs with recognized benefits. As the IPT paradigm matured it led to the current Integrated Product and Process Development (IPPD) and Integrated Product Development Teams (IPDT) vernacular and process. Another SE guidance source, DoD Directive 5000.1, states in the Collaboration section that "…programs shall maintain continuous and effective communications with each other by using Integrated Product Teams (IPTs)" (E1.1.2., Enclosure 1 p. 5). The SMC SE Primer similarly states:

> The key organizational building blocks are Integrated Product Teams (IPTs) and cross-product teams such as System Engineering and Integration Teams (SEITs) ….Each Contractor IPT is assigned full Responsibility, Authority, and Accountability (RAA) for its assigned products. (p. 148).

The Space Vehicle Systems Engineering Handbook, in sec 1.6.1, corroborates the theme by saying "A proven method of improving the efficiency of the development process is by establishing working groups and IPTs." (p. 9) It also states "The program office should ensure that IPTs are employed on the program as an element of SE, SV SE, and subsystem and unit design management implementation." (p. 9). Finally the DAG corroborates the above guidance and expands specifically on the SE role in IPTs with

> Systems engineering participates in the IPPD through a systems engineering working-level IPT (SE WIPT). The program lead or chief engineers should establish an SE WIPT to support the accomplishment of all systems engineering tasks and support efforts. (p. 172)

b. SASSA Tailored IPT Structure as Implemented

(1) SASSA Government Team Organization. The current SASSA government team program structure is highly a function of the SASSA programs growth over time. In the spring of 2007, a single Air Force officer was in charge of the "SASSA project." SASSA was one of a dozen projects assigned to the Air Force officer to oversee. When SASSA received its requested funding, the officer was authorized to hire contracted Systems Engineering and Technical Assistance (SETA), Aerospace Corporation (FFRDC) technical support, and was authorized to utilize another junior officer, partial time, in the late summer and fall of 2007. This pattern followed as the project solidified in maturity and scope definition with the team following suit to its current size. From one officer full time, to two, then three and so on to its present size of three officers, one full-time aerospace, five full-time SETA support staff, and various part-time support specialty personal (i.e., scheduling and FFRDC technical specialty expertise).

Early in the program, there was a conscious choice to not implement an IPT structure. The SASSA program was an aggressive, fast-paced program with high expectations to deliver on. There was a lot to be accomplished with very little resources in the government office in just getting the project started. A strategy was adopted from the beginning that the entire team was responsible for knowing, reading, and accomplishing everything. The SASSA team operated as a "badgeless" team, adopting a flat organizational structure. For SASSA to be effective in starting up quickly then all people needed to work and to contribute in a variety of fields that crossed many traditional roles. In this manner, the entire team could be current on all events and involved in all decisions. Specific tasks were volunteered for or assigned to be executed by the officer in charge using the "best athlete" mentality. In this way, the team's experience and skills were maximized across the program as everyone was exposed to everything. The best person for the job took the responsibility of accomplishing specific tasks or was assigned to specific tasks to maximize efficiency. This structure avoided personnel being able to "hide" under IPT titles and only do what was directly applicable to their IPT. Having these types of potential inefficiencies could create significant drains in a small team who needed everyone contributing across the board, regardless of IPT role.

As the full scope of the SASSA program was realized, to include a dual contract award (later scaled back to one), two full SASSA systems being procured, and firm relationships on two separate host vehicles, it was clear greater organization was necessary. The total body of possible information on the program became too large for the previous "everyone knows everything" mentality. Thus, a pseudo IPT structure was adopted. This was pseudo in the sense that, for the first time in the SASSA organization structure, an individual was assigned a particular specialty. For SASSA, this was two individuals—a software lead and ground lead. Even in this new configuration with two focus area leads, there are still no IPTs. These individuals are responsible for their particular area but do not exist as or within an IPT, nor do they lead an IPT for that subject. All personnel still perform in a "floating" mode as cross program help, including these two leads, albeit in a secondary role. For example, multiple SETA staff have experience in a variety of areas including program management, prior military acquisition experience, business, contracts, security, senior-level technical knowledge, and systems engineering. These personnel maintained a high resolution of knowledge on all aspects of the program and bolstered areas as needed, without existing in a specific IPT or lead role.

(2) SASSA Contractor Team IPT structure. The SASSA program required both contractors to adopt a conventional IPT structure as part of the proposal process. This organizational structure remained throughout the contractor's contractual period of performance. There was no modification of this aspect of standard SE guidance on the SASSA program.

c. Comparison of Standard Guidance to SASSA

The SASSA program tailored standard SE guidance in one significant respect. This was to intentionally *not* adopt a strict IPT structure for the government team at any point in the program. Even currently, the structure reflects more that certain individuals have areas of focus rather than being the lead of an IPT element. This is also made clear by the lack of complete IPT elements across the current structure. For example, there is no space segment or single SE lead. The primary reason for SASSA government team not adopting a strict IPT structure was an attempt to implement a strategy to better maximize the efficiency of the government team in accomplishing the large amounts of diverse work.

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V. EVALUATION OF SASSA TAILORED SYSTEMS ENGINEERING PROCESSES

A. INTRODUCTION

This chapter assesses the standard SE processes that have been tailored for their contributions, positively and negatively, towards achieving a rapid space acquisition in the SASSA program. The utility of this assessment is aimed at providing recommendations for utilization of selected tailored SE processes for similar acquisition projects, as well as capture historical information for the reader. The lessons learned on this program, specific to a rapid space acquisition and the unique attempts made in both effort and methodology, may be of usefulness for similar programs in the future.

B. STANDARD CRITERIA FOR EVALUATING TAILORED PROCESSES

This section identifies criteria by which each of the tailored SE processes can be judged against in assessing whether the process was a positive or negative contribution in accomplishing the SASSA rapid space acquisition. These criteria describe various aspects of value in the tailored processes. The criteria are:

- Meeting program technical or programmatic objectives
- Reducing cost
- Maintaining or shortening schedule
- Contributing to the ease of the SE process
- Contributing to the quality of the SE process

C. SASSA TAILORED SYSTEMS ENGINEERING PROCESSES EVALUATION

1. Requirements Development

The major deviations from the SE guidance for Requirements Development are summarized as:

- SASSA did not utilize the JCIDS (ICD or CDD) or their development approaches as suggested in SE guidance
- SASSA did not have any formal stakeholder input
- SASSA did not utilize formal KPP/KPA's at the government level

The tailored implementations by SASSA are summarized as:

- SASSA assumed the congressional language as a starting place and developed program objectives and a TRD traceable to these objectives
- SASSA applied internal expertise and understanding of SSA to the needs of the SASSA system in requirements development
- SASSA utilized a minimum number of requirements in the TRD
- SASSA utilized an Excel spreadsheet to capture requirements traceability, capabilities, and verification information for ease of assessment and effectiveness
- SASSA developed a three volume SASSA SIS ICD for instrument and SV hosts to understand the SASSA interfaces

The approach the SASSA program implemented for tailoring the standard SE guidance for the requirements development process approach was assessed as very successful towards completing the rapid space acquisition. The process tailoring enabled the program to develop sufficient requirements for the rapid acquisition quickly. The process rigorously decomposed these requirements and ensured appropriate mapping from the original congressional language, to the programs core objectives, to the TRD requirements. Total program cost and schedule was saved through implementing wise choices in software tools, which optimized efficiency of assessment and depth of SE review. Establishing a minimum number of TRD requirements also streamlined efforts and reduced total requirements management overhead. This rapid process established solid requirements quickly, allowing the program to contribute to future SASSA programs' SE effort in the development of the SIS ICD volumes. In summary, the program was able to complete all the requirement documents to ensure that all the design reviews were completed on schedule. The requirements development process completely captured the customer needs, which are currently being verified as part of system tests. The results of the tailored processes only contributed to efficiency and expediency in the overall acquisition.

2. Functional Architecture Design and Synthesis

The major deviations from the SE guidance for Functional Architecture and Design Synthesis are summarized as:

- SASSA constrained the possible architecture and synthesis solutions by constraining implementations with the technical requirements

The tailored implementations by SASSA are summarized as:

- SASSA performed an analysis of alternative type study with a reference system design
- SASSA implemented a particular architecture as a starting place for contractor design including a secondary payload configuration, high TRL hardware, and defined payload elements with space, ground, and testbed segment delineations

The approach the SASSA program implemented for tailoring the standard SE guidance for the Functional Architecture and Design Synthesis process was assessed as very successful towards completing the rapid space acquisition. The tailored process constrained the scope of the problem to be solved given the funding, schedule, and resources available. This focused contractor efforts that aided in maintaining efficient expenditure of cost and schedule resources in achieving a successful design implementation. The decision to make some of the design synthesis choices within the government office as a starting place moved the contractor design implementation farther along the developmental process that was advantageous in meeting the rapid acquisition timeline. Achieving this design earlier in the timeline also allowed more rigorous SE review earlier in the program. Given the constraints as well as the specific set of instruments the SASSA team gave to the contractor, it eliminated any trade analysis and/or indecisions. This could have cost the program precious time in the architecture definition phase and delayed the start of specific design. Overall, this tailored process used by SASSA is assessed to have been a critical positive contributor, essential in achieving successes in the program this far in completing the rapid space acquisition.

3. Standard Systems Engineering Plans

The major deviations from the SE guidance for use of Standard Systems Engineering Plans are summarized as:

- SASSA did not develop a standard SEP/SEMP, SEMS and/or SEDS
- SASSA did not require their contractors to develop, maintain, and update a standard government approved SEP/SEMP, SEMS and SEDS

The tailored implementations by SASSA are summarized as:

- SASSA captured SE methodologies by implementing a multipronged approach:
    - RFP evaluation criteria for processes for Systems Engineering and Software Engineering Management
    - Contractor's proposal response to the RFP for these criteria; this articulated the contractors process and plan without requiring a standard SEMP
    - (IMS) – this captured major SE milestones and interrelations to other critical events
    - Specification of required government approved contractual deliveries (CDRLs) CM, PMP, and SDP
    - Team decided before program execution how it would execute SE in the program – captured in a briefing

The approach the SASSA program implemented for tailoring the standard SE guidance for utilizing Standard Systems Engineering Plans was assessed as very successful towards completing the rapid space acquisition. This SASSA process implementation is an excellent example of how SASSA was able to effectively tailor a standard SE process to make positive contributions towards a rapid space acquisition. The upfront RFP planning and acquisition requirements which the contractors had to respond to, as well as the discussions as to how the SASSA team would manage the development contracts accomplished the objectives of a standard SEMP/SED without the expenditure of the associated lengthy time and resources. Additionally, the contractor proposed to leverage a standard SEMP from company "Command Media," which helped set the framework of how to conduct business. This was stated at the program kick-off and agreed to by the SASSA program office, which eliminated the need for a lengthy SEMP development activity. Overall, the tailored approach implemented by SASSA ensured SE objectives for the program were met, shortened the overall schedule by reducing the overall tasks to be accomplished, and contributed to cost savings by optimizing time and task expenditures.

4. Use of Systems Engineering Leads

The major deviations from the SE guidance for the use of Systems Engineering Leads are summarized as:

- SASSA did not appoint or use a SE lead in the government team

The tailored implementations by SASSA are summarized as:

- SASSA performed SE as a group and by consensus on the government team

The approach the SASSA program implemented for tailoring the standard SE guidance for the use of Systems Engineering Leads was assessed as a neutral contribution towards completing the rapid space acquisition. The SASSA program was able to execute and maintain excellent SE oversight, but it could not be attributed to the process tailoring. Rather the SASSA team exploited an advantageous situation with many on the SASSA team having education and predisposition for doing systems engineering. A program that chooses to implement this same tailoring approach risks not ensuring that adequate expertise in SE is a part of the program or that adequate SE work is being accomplished on the program. The conclusion is the successes on the SASSA program in this area were due more to the team composition than the tailoring of the standard SE process. This approach should be viewed as a risk for any program considering this implementation, noting that success is critically dependant on team composition throughout the life of the program.

5. Technical Reviews

The major deviations from the SE guidance for Technical Reviews are summarized as:

- SASSA milestones were out of order from guidance
- SASSA did not develop entry and exit criteria before the program was started nor did it put it in the SEM or SEMP
- SASSA did not use a completely independent team to review technical milestones
- SASSA did not use incremental milestone reviews from unit to system for PDR and CDR

The tailored implementations by SASSA are summarized as:

- SASSA performed SRR before IBR as its first major milestone
- SASSA developed entry and exit criteria within the government team 8-12 wks prior to the event
- SASSA utilized FFRDC and outside organizational experts for IDR/CDR (with every review)
- SASSA held a single milestone event for all elements with exception of Software at SRR (SSR)
- SASSA performed a rigorous early technical review preparation process (30 day plan)

The approach the SASSA program implemented for tailoring the standard SE guidance for Technical Reviews was assessed as very successful towards completing the rapid space acquisition. The first positive contribution from the modification of this guidance by SASSA is an early aligning and understanding by the contractor of the system requirements. This was a critical factor is setting the program off on the right foot for both a technical understanding and the opportunity to plan the program resources. The next benefit of the tailored guidance was the use of “semi-independent” experts to review material at the SASSA milestones. This outside perspective added to the rigor of each event in ensuring adequate SE and design principles had been used. An additional benefit to the SASSA tailored guidance was in saving schedule and resources (ultimately cost) by not performing incremental technical review events preceding the system technical reviews. SASSA was able to take advantage of its smaller system and still accomplish rigorous technical reviews. The final positive contribution was the technical event preparation and review process developed by the SASSA team. This process allowed for early review and approval prior to the event, which allowed for more efficient maintenance of technical momentum in the program and minimizing the risk of significant schedule delays. This also ensured the meeting of program objectives by upfront review as a forcing function for maturity assessment. By uncovering issues early in milestone preparation process SASSA minimized the risk of spending time and resources addressing design issues and actions items discovered for the first time at the event.

The SASSA program could have been even more efficient if had followed the aspect of the standard guidance for completing the entry and exit criteria before the program start as well as described the milestone event-review preparation process. This would have allowed the contractor to plan accordingly with time and resources. This may have contributed to reducing the current cost overrun in the SE cost element in the program.

Overall, the process tailoring by the SASSA program for Technical Milestones was beneficial in the success of maintaining the milestone schedule of events from kick-off through CDR and ensuring in depth SE and design reviews.

6. Integrated Product Team (IPT) Structures

The major deviations from the SE guidance for the use of Integrated Product Team's (IPT) are summarized as:

- SASSA government team did not utilize a rigid IPT structure, even late into the program

The tailored implementations by SASSA are summarized as:

- SASSA utilized a flat, organizationally "badgeless" team

The approach the SASSA program implemented for tailoring the standard SE guidance for utilizing IPTs was assessed as very successful towards completing the rapid space acquisition. The implementation of the "flat" organizational structure was a significant positive contribution to the overall SASSA rapid acquisition. The lack of strict IPT stovepipes allowed synergy among the few team members, which was critical to accomplishing the large volume and technical depth in a variety of fields in a short time. It allowed all members of the team a holistic view of the program as all members were current on all topics. It efficiently used the resources of the team and minimized the tendency to focus only on an individual IPT or subject. Overall, the SASSA modification of the SE guidance to implement IPTs was assessed to be a great positive contributor towards achieving this rapid space acquisition. The composition of the SASSA team and individual traits of the members allowed for a more beneficial application of resources in executing the program than could be had by implementing an IPT structure.

D. CHAPTER SUMMARY

Table 15 summarizes the assessment of the SASSA tailored standard SE guidance and indicates its contribution towards accomplishing a rapid space acquisition.

Modified SE Process	SASSA Modifications	Benefits	Risks	Contribution
Requirements Development	- No JCIDS process involvement/ utilization - No formal stakeholder involvement - No KPP/KPA's - Strong traceability from goals to req.'s	- Clear traceability from original goals to req.'s - Allowed program to move more quickly than a JCIDs program	- Potential lack of insight into final capability with no interim KPP/KPA assessment - Output capability of program not useful to	Positive

			users (potential)	
Functional Architecture and Design Synthesis	- Gov imposed design aspects (TRL, HW units, heritage req.'s) - Defined Functional elements - Minimize inefficient/wasted design effort	- Focus program on likely solutions - High probability of plausible options	- Miss inventive or creative solutions - "Constrain out" better solution	Positive
Standard SE Plans	- No government or contractor SEP,SEMP, SEMS, or SEDS - Use of RFP, IMS, CDRLs for SE process - Program meetings to define processes - Use of Contractor processes	- Saved resources for Gov and contractor - Less documentation - Less overall tasks	- Gov does not see potential deficient SE plans of contractor - Gov is unclear on its own SE plans/process	Positive
Use of Systems Engineering Leads	- No dedicated SE lead on government team - Team SE process	- More than one SE - Diverse, collaborative SE tracking	- Lack of adequate SE - Inconsistent SE process - Critically dependant on team composition	Neutral
Technical Reviews	- SRR before IBR - Entry/Exit criteria not generated before program initiation - Criteria not in SEM(P) - No completely independent reviewers - No incremental reviews	- Superior knowledge of program requirements for baseline planning - Understand program needs from the start - Save resources - Thorough reviews	- Contractor not understanding tech event criteria in planning resources for baseline - Under scope resources - Too much in one review for larger programs - Miss independent perspective	Positive
Integrated Product Teams (IPT's)	- "Flat", versatile government team structure vice IPT structure	- More expertise exposed to more tasks - surge capability for quick task completion - Entire team up to date on critical issues - Counteracts stove piped thinking - Good fit for minimal Gov resources - Entire team aware of program status	- Too much information for all to absorb as program grows - Lack of ability to have needed depth in focused area in large programs - Lack of consistent follow through/tracking of single segment issues	Positive

Table 15. Summary of Tailored Standard Systems Engineering Processes

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VI. APPLICATION OF STUDY

A. INTRODUCTION

This study would not be of any use or utility, in the view of the researcher, if it were not for some possibility of practical application that has the ability to live beyond the simple historical analysis of the SASSA program. The first and foremost intention for the application of this study is for similar programs to be able to observe elements of the SASSA program, learn from the perceived successes and failures, and make informed decisions for how to optimize their program. The second intention is to provide useful information for the general education of the systems engineering community in order to stay current and relevant in the current application of SE on a DoD space program. Space acquisitions is a dynamic and changing field and will only become more so as our reliance on and capabilities in space drive greater and greater population of space. Threat warning capability for satellites is currently on the verge of universal propagation to the same degree that is prevalent on terrestrial airframes and military ships. Understanding how SE is being applied in the far corners of the growing fields of acquisitions is essential to staying relevant and current. The third intention for the application of this study is to provide readily usable recommendations for rapid-paced acquisitions. The final intention is to provide feedback and recommendations for the improvement of the overall DoD acquisitions process, specifically in the early Prephase A portions of development and systems engineering.

B. OBSERVATIONS

- Most standard, military based SE guidance is primarily SE technical management (vice SE processes)
- Most industry SE guidance is so high level it is either not useful or difficult to apply/implement in a DoD military acquisition

- There is little if any SE guidance for non JCIDs/formal acquisitions, despite a large number of military programs falling outside this realm
- The apparent source of SE processes (not technical management guidance) knowledge is either learned by experience, found in contractor "command media," or learned in academia. This relegates SE learning by handing down "over the campfire" by those more experienced who tutor younger engineers or via higher education
- Standard SE guidance must be tailored/deviated from to achieve a rapid acquisition
- Team composition is equally as important as the tailoring of standard SE processes in rapid space acquisitions
- By not providing directly applicable standard guidance, the larger DoD acquisition system creates an inherent risk and inefficiency by allowing non JCIDS type, smaller programs to "fly under the radar" of current SE guidance
- Adherence to good SE processes is as important as having defined good SE processes
- Value added should be the strict criteria for whether or not a tailored or standard SE process is implemented
- "Better" is the enemy of "good enough"
- Tailoring, where possible, should apply lessons learned from other acquisition activities
- Rapid space acquisition s requires experienced and SE knowledgeable personnel – these programs are too short and consequences to dire to learn on the job
- Rapid space acquisition requires strong SE leadership to focus effort

C. RECOMMENDATIONS

1. Recommendations for the Systems Engineering Community

- Perform a survey of SE guidance for military acquisitions and ensure there is comprehensive coverage of SE processes (as opposed to SE technical management).
    - Publish a Primer which points to or consolidates this "how to do SE in the military" for ease of use and proliferation, focused on SE processes.

- Create a new SE guidance or append the present guidance which would instruct on how to practically implement and accomplish SE processes on non-formal/non JCID's programs.
- Create a new SE guidance or append the present guidance for recommendations on how to tailor standard guidance for non-formal/ non JCIDs programs.
    - Address the importance and relationship of the large number of small technology and acquisition efforts to the larger formal programs and JCIDS process. Good SE is needed even in these small programs to be efficient in technology maturation as it relates to larger programs.

- Continue to instruct in basic SE application and build a strong foundational knowledge of accomplishing SE processes in SE students.
    - Advocate for high levels of practical implementation instruction for doing SE in military programs at universities and especially in military higher education facilities.

2. Recommendations for Accomplishing Rapid Space Acquisitions

- Observe and consider the positive contributions made on the SASSA program by tailoring standard SE guidance
- Tailor standard SE guidance and choose quality teams using "value added" as a prime criteria
- Ensure processes proposed are followed throughout acquisition regardless of if they were tailored or not
- Assemble teams that have experienced and SE knowledgeable personnel as a "non-negotiable"
- Ensure processes proposed are followed throughout acquisition, regardless of if they were tailored or not
- Provide strong SE leadership on the team

D. AREAS FOR FURTHER RESEARCH

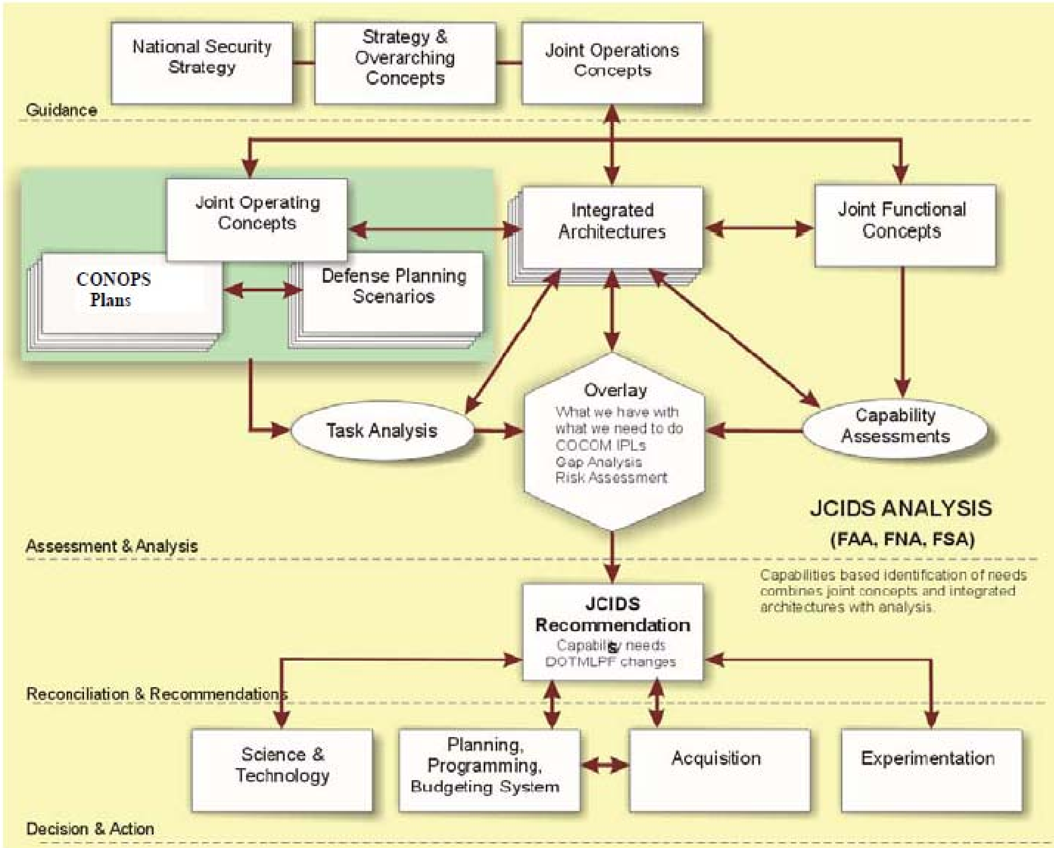
Recommended areas of further research fall into two main areas. The first is to take the assessments of tailored processes and compare them for validity to other programs of like size and scope. This undertaking would aid in determining whether the assessments of the tailored processes were accurate, whether the results were repeatable as evidenced by other programs, or whether additional processes could be added to the recommendations. Greater confidence in the recommendations of this study could be achieved if it is compared to a body of programs rather than this single instance.

The second area of additional research is to expand on the concept of developing standard SE processes guidance for smaller, Prephase A programs. This study could develop a series of aspects to include the validation of the link between smaller programs and standard JCID milestone programs (i.e., feeder programs), a more complete survey of material for guidance on smaller programs, or creating a draft of guidance that addresses various solutions for how standard SE guidance might look for smaller programs.

APPENDIX A. ACQUISITION DESCRIPTION SUMMARY

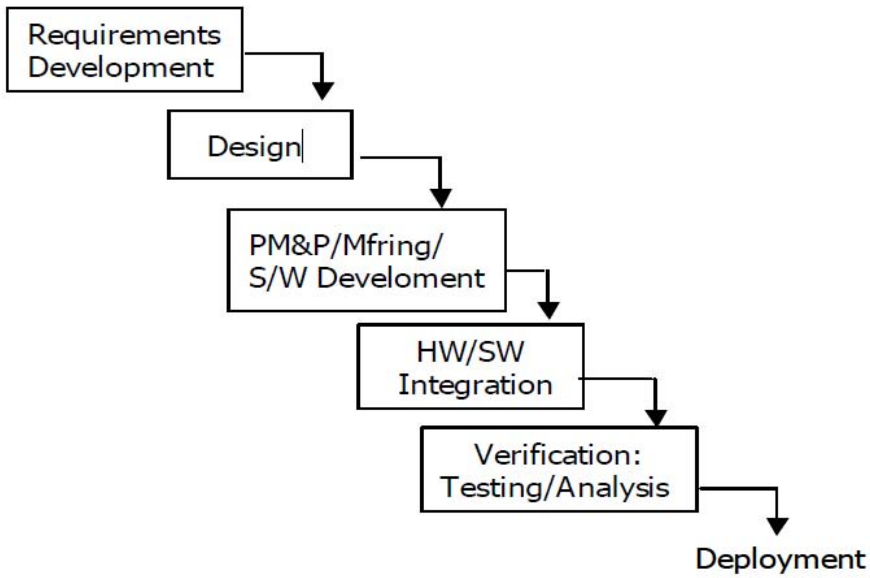
This brief summary is intended to accomplish two things. The first is to provide a working knowledge of formal acquisitions processes in the DoD as a context for the rest of the study. The second is to capture the somewhat unusual acquisition process SASSA has experienced relative to the formal JCIDS acquisition process in the DoD. It is worth noting, for background information, what the typical acquisition process is and its phases, what the normal products of each phase would be, and how SASSA differed. This will serve as a backdrop for the entire study, keeping in mind the focus of the study is to investigate the modification of typical SE processes.

A quick refresher on DoD acquisition process is helpful in understanding how the SASSA program differed in its start up. The Chairman of the Joint Chiefs Of Staff Instruction, JCSI 3170.01C, 24 June 2003 establishes the policies and procedures of the Joint Capabilities Integration and Development System (JCIDS) (SMC SE Primer, p. 39). The JCIDS development system is the current DoD architecture in which all major acquisitions are implemented. Included in this system is a means by which DoD acquisition needs are identified, investigated, and then flowed down further in the process. This top-down needs-identification process is depicted in the SMC SE Primer.

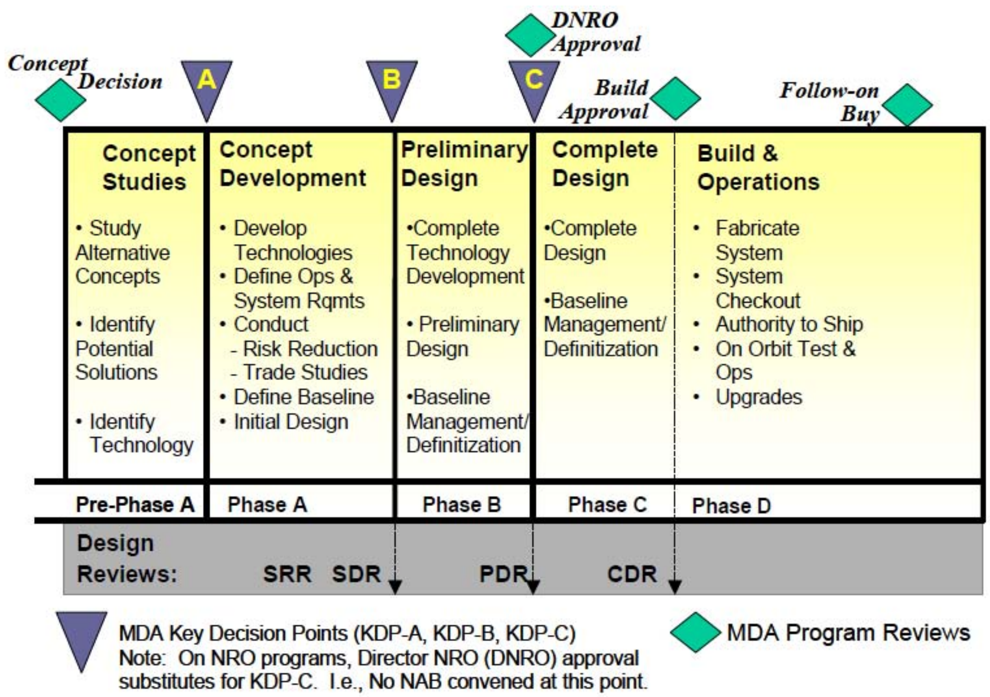


JCIDS top-down capability need identification process (SMC SE Primer, p. 40)

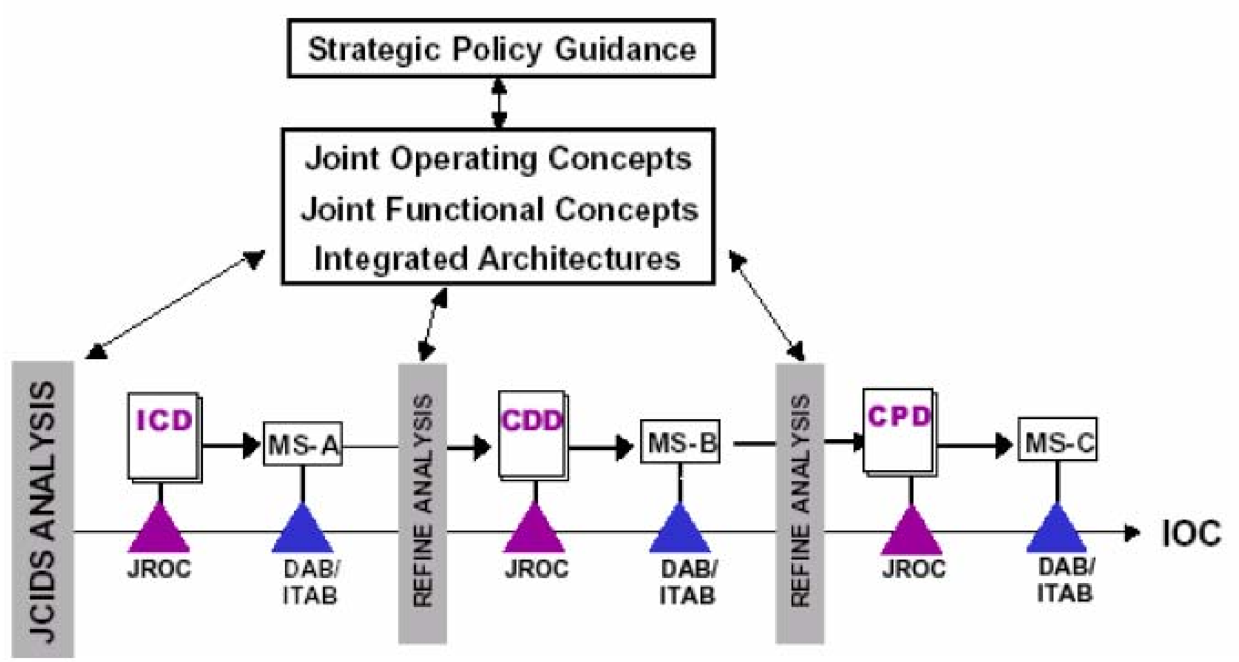
Once top-level needs have been identified, they are flowed to the next phase of the JCIDS process. The entire life cycle of the JCIDS process is depicted in both a simplified functional sense, as well as in the formal steps, as depicted in figures 1.6-1 and 2.2-1 (SV SE Handbook**)**. In general, the entire JCIDS process is broken into three major milestone phases: A, B, and C (SMC SE Primer, figure 12). Each phase is preceded by standardized and gated processes that have to be approved by the major authority placed over the acquisition.



(SV SE Handbook, p. 11) Simplified functional description of activities completed in the JCIDS process



(SV SE Handbook, p. 19) JCIDS Milestone steps



(SMC SE Primer, p. 41) Simplified JCIDS Milestone Steps

The formal JCIDS process can be described in detail in many sources, however the relevant aspect for this study is the initial phase where requirements have been identified or need to be identified and are initiated in the JCIDS process. In the JCIDS vernacular this is the Pre-milestone A phase or Prephase A. This phase, as with each of the phases, has a prescribed set of content that needs to be addressed and approved to move to the next phase.

The SV SE handbook describes the content that Prephase A is intended to capture by stating,

> Prephase A is characterized by development and evaluation of alternative concepts to the systems, a top-level description of needed capabilities (i.e., initial capabilities document), and definition of the CONOPS for those capabilities. Prephase A begins the capabilities/requirements evolution strategy and activities to develop and manage the requirements and documents. (sec 2.2.1.1.1.1., p. 22).

The key aspect of this phase is that it is forward looking to technology maturity and capability development in the form of hardware design and build. This means that all the activities are primarily planning and analysis based, resulting in documentation and direction for future development of hardware. This brief summary is sufficient at this point to provide an adequate context of understanding for the rest of this study without describing the remaining aspects of the DoD JCIDS process.

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APPENDIX B. DEFINITION OF TERMS

This study makes repeated use of terminology that needs to be defined in order to create a common understanding for the reader. The concepts discussed here are not intended to establish new definitions in the larger acquisition community but is strictly focused to guide the reader to understand the intended meaning behind commonly used phraseology in the following chapters and sections.

Typical or Standard: Used to indicate that a particular systems engineering process is articulated in a published and established text viewed by industry or the military as a standard or reference text.

Tailored: Used to indicate that a typical or standard systems engineering process has been changed in some form or implementation from that which was originally described or defined in the original source guidance text.

Effective: Used to indicate that a particular tailored standard process or unique process implemented was advantageous towards the overall goal of completing the SASSA rapid acquisition as close to the ideal as defined by a) the original baselined delivery date of October 2010; b) the original baselined cost estimate as defined at contract award and c) the baselined functional and performance capability defined in the government technical requirements document placed on contract. The antonym of this phraseology will also be utilized in this study to describe SE processes implemented that have the opposite effect.

Success or Successfully Implemented: Used here to capture a judgment that a particular tailored or unique SE process implemented in the SASSA program significantly contributed to the current state of the SASSA program. In this study, all SE processes implemented that positively contribute towards meeting the goal of the rapid acquisition are deemed successful. There is an inherently subjective nature to this type of judgment. As such, in all cases possible there will be a quantifiable justification made. In other cases, this will not be possible and will have to rest on the logic of the case made for a positive contribution to completing the SASSA program on its ideal objectives for schedule, cost, and capability as defined in the contract. The antonym of this phraseology will also be utilized in this study to describe SE processes implemented that have the opposite effect.

Acquisition Product: Used here to capture the complete set of resulting products of an acquisition program. This includes all hardware, software, study results and analysis, and resulting experience.

Rapid Acquisition: Used here to denote a contractually obligated acquisition effort that, relatively speaking, attempts to complete either a typical amount of "acquisition product" on a compressed schedule or an above average amount of "acquisition product" on a typical schedule. Typical here is a subjective judgment for what appears to be standard for the industry of space acquisition and at the Space and Missile Systems Center (SMC). For example, it is not typical to deliver flight hardware in two years. This would be considered an aggressive schedule. To deliver two fully integrated flight payload systems with space, ground, and testbed segments is very A-typical for the space acquisition standard, including at SMC.

Program and Project: In the standard sense of definitions derived from standard SE guidance texts programs and projects are different. The Aerospace Corporation SV SE Handbook provides these definitions where "a project is an effort with a specific objective and end point. For example, a project might be to develop, launch, operate, and dispose of a SV. By contrast, a program is an ongoing effort, without a defined end, that may involve a number of projects. GPS is an example of a program. In common usage, these terms are often used interchangeably." (p. 21). By the standard definition, SASSA is a project, but is referred to in common usage as a program in this study.

Payload: The term payload is used here to denote a set of units on a larger satellite space vehicle, which function together for a specific purpose. Satellites often have primary and secondary payloads.

Spacecraft or Bus: This term is used to identify the elements of a satellite, which are not the payloads. It includes the flight computer, power, attitude control, solar panels, etc.

Space Vehicle: This term is used to define the spacecraft plus payloads on a satellite

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